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DEFENSE COMMUNICATIONS SYSTEM (DCS)

ENGINEERING-INSTALLATION STANDARDS MANUAL (DCA CIRCULAR 175-2A)

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DEPARTMENT OF DEFENSE

Defense Communications Agency

Washington 25, D.C.

1. This standard has been approved by the Defense Communications Agency (DCA) for use in the Defense Communications System (DCS).

2. This standard is mandatory for use effective 1 April 1963. Deviations from this standard will be made only after approval of the Defense Communications Agency.

3. This standard is not complete with this issue. Additional sections will be published as approved.

4. Comments regarding this standard should be addressed to the Director, Defense Communications Agency, ATTN: Code 343, Washington 25, D.C.

FOR THE DIRECTOR:

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LIST OF EFFECTIVE PAGES

TABLE OF CONTENTS

CHAPTER I

SCOPE

1.1 DCS Engineering-Installation Standards

1.1.1 *Definition.* Engineering-Installation Standards as they apply to the Defense Communications System (DCS) are those standards which provide quantitative and qualitative values and measures for obtaining uniformity of controls governing engineering and installation of equipment, facilities, and systems. Equipment, facilities, and systems must meet these standards upon completion of engineering and installation, and prior to acceptance for operational use.

1.1.2 *Examples.* Included in the category of DCS Engineering-Installation Standards are: Standards for system engineering such as signal level, impedances, modulation rate, frequency and time tolerances, distortion tolerances, and measurement techniques; standards for field engineering such as antenna design and orientation, and transmission line design; and standards for installation engineering such as equipment arrangements and layout, uniform construction requirements, and site preparation.

1.1.3 *Need for DCS Engineering-Installation Standards.* Interoperability and uniform high quality performance of all DCS components requires that they be engineered to high universal standards. New requirements may be placed upon segments of DCS facilities formerly used by a single military service and not originally designed nor engineered for operation with other systems. These components of the DCS must be reengineered, where necessary, to meet these standards so that interoperability and uniform capability will be assured. Engineering of future DCS facilities must conform with these standards for the same reason.

1.1.4 *Application and Use of Standards.* These standards are to used when preparing specifications for new components of the DCS or when modifying existing systems. They should be cited and/or quoted when appropriate. They will be the basis upon which DCA will review detailed engineering plans of proposed DCS facilities. All DCS facilities will be inspected periodically for adherence to these standards.

1.1.5 *Relation of DCS Engineering-Installation Standards to Other DCS Standards.* The DCA will prescribe the utilization of standards in three areas; development, engineering, and operations. Standards are—

(a)	Design	MIL-STD-188(), published by OSD.
(b)	Engineering	DCS Engineering-Installation Standards published by DCA (this circular).
(c)	Operations	DCS Operating Standards published by DCA (DCA Circular 55-1).

All DCS standards follow the same general outline. The paragraph headings are the same down to the first decimal place of the numbering system. This is for the purpose of cross-referencing between standards when appropriate.

Design standards (MIL-STD-188) and DCS Operating Standards, and Engineering-Installation Standards are published as separate documents.

1.1.6 *Technological Level of Standards.* The standards contained in this document are set no higher than the current technological capability of industry. No attempt is made to anticipate future technical advances. Such advances will be made a standard after they are accomplished and proven facts. Keeping DCS Engineering-Installation Standards up to the level of achievable technology will require continued revision of the standards; this will be accomplished as required.

CHAPTER II

TERMS AND DEFINITIONS

ADDRESS. The destination of the message in a communication system or the storage location of information in a data processing system.

ALPHABET. *See* Digital Alphabet *or* Code Set.

ALPHABET TRANSLATION. That process whereby the meaning in a particular bit structure in a particular code is conveyed to one or more different alphabets in the same or different code.

ALPHANUMERIC. Alphabetic and numeric; including letters, numbers, and symbols.

AMPLITUDE MODULATION. *See* Modulation, Amplitude.

ANALOG SIGNAL. A nominally continuous electrical signal that varies in some direct correlation to a signal impressed on a transducer. The electrical signal may vary its frequency or amplitude; for instance, in response to changes in phenomena or characteristics such as sound, light, heat, position or pressure.

ASSIGNED FREQUENCY. *See* Frequency.

ATTENUATION. The action by which, or the result in which, the power of an electrical signal is decreased; expressed in db.

ATTENUATION, ECHO. *See* Echo Attenuation.

BALANCED. Electrically symmetrical with respect to ground.

BANDWIDTH, OCCUPIED (for a transmitter).

(a) The difference between the highest and the lowest emission frequencies, in the region of the carrier or principal carrier frequency, beyond which the amplitude of any frequency resulting from modulation by signal and/or subcarrier frequencies and their distortion products is less than 5 percent (−26 db) of the rated peak output amplitude of—

(1) The carrier or a single-tone sideband, whichever is greater, for single-channel emission; or

(2) Any subcarrier or a single-tone sideband thereof, whichever is greater, for multiplex emission.

(b) Bandwidth, Necessary. For a given class of emission, the minimum value of the occupied bandwidth sufficient to insure the transmission of information at the rate and with the quality required for the system employed, under specified conditions. Emissions useful for the good functioning of the receiving equipment as, for example, the emission corresponding to the carrier systems, shall be included in the necessary bandwidth. (This is used for frequency assignment purposes.)

BANDWIDTH, NOMINAL. The maximum band of frequencies, inclusive of guard bands, assigned to a channel. (Not to be confused with the term radio frequency emission.)

BASEBAND. In the process of modulation, the frequency band occupied by the aggregate of the transmitted signals when first used to modulate a carrier. The term is commonly applied to cases where the ratio of the upper to the lower limit of the frequency band is large compared to unity.

(a) BASEBAND, MULTIPLEX. The frequency band occupied by the aggregate of the transmitted signals applied to the facility interconnecting the multiplexing and radio or line equipments. The multiplex baseband is also defined as the frequency band occupied by the aggregate of the received signals obtained from the facility interconnecting the radio or line and multiplexing equipment.

(b) BASEBAND, RADIO. The frequency band available for the transmission of all the combined telephone channels and/or other communication channels.

(c) MULTIPLEX BASEBAND SEND TERMINALS. The point in the baseband circuit nearest the multiplex equipment from which connection is normally made to the radio baseband send terminals or intermediate facility.

(d) MULTIPLEX BASEBAND RECEIVE TERMINALS. The point in the baseband circuit nearest the multiplex equipment from which connection is normally made to the radio baseband receive terminals or intermediate facility.

(e) RADIO BASEBAND SEND TERMINALS. The point in the baseband circuit nearest the radio transmitter from which connection is normally made to the multiplex baseband send terminal or intermediate facility.

(f) RADIO BASEBAND RECEIVE TERMINALS. The point in the baseband circuit nearest the radio receiver from which connection is normally made to the multiplex baseband receive terminals or intermediate facility.

BAUD. The unit of modulation rate. One baud corresponds to a rate of one unit interval per second. The modulation rate is expressed as the reciprocal of the duration in seconds of the unit interval. Example: If the duration of the unit interval is 20 milliseconds, the modulation rate is 50 bauds.

BIAS DISTORTION. *See* Distortion, Bias.

BINARY CODE. A code composed of a combination of entities, each of which can assume one of two possible states.

BINARY DIGIT. An information state in binary notation (e.g., 0 to 1).

BINARY NOTATION. A scheme for representing numbers characterized by the arrangements of digits in sequence with the understanding that successive digits are interpreted as coefficients of successive powers of the base two.

BINARY NUMBER. A number expressed in binary notation.

BIT. A contraction of the term binary digit. There are several types of bits:

(a) Check Bit. A bit associated with a character or block for the purpose of checking the absence of error within the character or block.

(b) Erroneous Bit. A bit which is not in accordance with that which should have been received.

(c) Information Bits. Those bits which are generated by the data source and which are not used by the data transmission system.

(d) Overhead Bits. All bits other than information bits.

(e) Service Bits. Those overhead bits which are not check bits (i.e., request for repetition, numbering sequence, etc.)

BLOCK. A group of bits, or n-ary digits transmitted as a unit over which an encoding procedure is generally applied for error-control purposes.

BREAK. To break, in a communication circuit, is for the receiving user to interrupt the sending user and take control of the circuit; used especially in connection with half-duplex telegraph circuits and two-way telephone circuits equipped with voice-operated devices.

BROADBAND SYSTEM. *See* Wideband System.

BROADCAST. *See* Operation.

BUFFER, DATA. A storage device used to compensate for a difference in rate of flow of information or time of occurrence of events.

CARRIER.

(a) A wave suitable for modulation by the intelligence to be transmitted over a communication system. The carrier can be a sinusoidal wave or a recurring series of pulses. *See also* Subcarrier.

(b) An unmodulated emission.

CARRIER FREQUENCY. *See* Frequency.

CARRIER NOISE LEVEL. The noise level produced by undesired variations of a carrier in the absence of any intended modulation.

CARRIER POWER. *See* Transmitter Power Output Rating.

CENTRAL OFFICE *See* Switching Center.

CHANNEL. A means of one-way transmission. Several channels may share a common path as in carrier systems; in this case each channel is allocated a particular frequency band which is reserved to it.

CHARACTER AND BIT COUNT INTEGRITY. That condition in which the precise number of characters or bits that are originated in a message text (in the case of message communication) or per unit time (in the case of a user to user connection) are preserved.

CHARACTER INTERVAL. The total number of unit intervals (including synchronising, intelligence, error checking or control bits) required to transmit any given character in any given communications system. Extra bits which are not associated with individual characters are not included.

CHECK BIT. *See* Bit.

CIRCUIT. A means of bothway communication between two points, comprising associated "go" and "return" channels.

CIRCUIT SWITCHING. *See* Switching Circuit.

CLOCK. A reference source of timing information for a machine or system.

CLOSED-CIRCUIT WORKING. A method of single-current operation in which a current flows in the circuit while the transmitting device is at rest.

CODE (telegraph or data). A system of rules and conventions according to which the telegraph signals forming a message or the data signal forming a block should be formed, transmitted, received and processed.

CODE CHARACTER. The representation of a discrete value or symbol in accordance with a code. *See* Digital Alphabet *or* Code Set.

CODE CONVERSION. The process by which a code of some predetermined bit structure (for example, 5, 7, 14 bits per character interval) is converted to a second code with more or less bits per character interval. No alphabetical significance is assumed in this process. In certain cases such as the conversion from start/stop telegraph equipment to synchronous equipment a code conversion process may only consist of discarding the stop and start bits, adding a sixth bit to indicate the stop and start condition. In other cases, it may consist of addition or deletion of control and/or parity bits.

CODE ELEMENT. One of a finite set of parts of which the characters in a given code may be composed.

CONFERENCE. *See* Cperation.

CROSSTALK. The phenomenon in which a signal transmitted on one circuit or channel of a transmission system is detectable in another circuit or channel.

CROSSTALK COUPLING (between a disturbing and a disturbed circuit). The ratio of the power in the disturbing circuit to the induced power in the disturbed circuit observed at definite points of the circuits under specified terminal conditions; expressed in db.

DATA (analog or digital). Material transmitted or processed to provide information, or to control a process.

DATA SINK. The equipment which accepts data signals after transmission.

DATA SOURCE. The equipment which supplies data signals to be transmitted.

DATA TERMINAL. Equipment employed at the end of a transmission circuit for the transmission and reception of data. It may include end instruments or signal converters or both.

dba. *See* Noise.

dbaO. *See* Noise.

dbm. db referred to one milliwatt; employed in communication work as a measure of absolute power values. Zero dbm equals one milliwatt. *See* Noise.

dbm, PSOPHOMETRICALLY WEIGHTED. *See* Noise.

dbmo. *See* Noise.

dbmOp. *See* Noise.

dbr. *See* Noise.

dbrn. *See* Noise.

DEMODULATION. A process wherein a wave resulting from previous modulation is employed to derive a wave having substantially the characteristics of the original modulating wave. *See* Restitution.

DESIGN OBJECTIVES. Electrical performance characteristics for communication circuits which are based on reasonable engineering estimates of the performance required but which have not been confirmed by actual measurement of operating circuits. A design objective is in reality a projected standard to serve until such time as a system standard can be established by actual measurement under operating conditions of the developed circuit. *See also* System Standards.

DIGITAL ALPHABET OR CODE SET. A table of correspondence between characters and functions and the bit structures which represent them.

DIGITAL SIGNAL. A nominally discontinuous electrical signal that changes from one state to another in discrete steps. The electrical signal could change its amplitude or polarity, for instance, in response to outputs from computers, teletypewriters, etc. Analog signals may be converted to a digital form by quantizing.

DISTORTION, AMPLITUDE VS. FREQUENCY (of a transmission system). The distortion caused by the nonuniform attenuation, or gain, of the system, with respect to frequency, under specified terminal conditions.

DISTORTION, BIAS. Distortion affecting a two-condition (or binary) modulation in which all the significant intervals corresponding to one of the two significant conditions have uniformly longer or shorter duration than the corresponding theoretical durations.

DISTORTION, CHARACTERISTIC. Distortion caused by transients which, as a result of modulation, are present in the transmission channel and depend on its transmission qualities.

DISTORTION CYCLIC (of telegraph signals). Distortion which is neither characteristic, bias, nor fortuitous and which, in general, has a periodic character. Its causes are, for example, irregularities in the duration of contact time of the brushes of a transmitter distributor, or interference by disturbing alternating currents, etc.

DISTORTION, DEGREE OF.

(a) Distortion, Degree of Start-Stop. Ratio to the unit interval of the maximum measured difference, irrespective of sign, between the actual and theoretical intervals separating any significant instant of modulation (or of restitution) from the significant instant of the start element immediately preceding it. The degree of distortion of a start-stop modulation (or restitution) is usually expressed as a percentage.

(b) Degree of Individual Distortion of a Particular Significant Instant (of a Modulation or of a Restitution). Ratio to the unit interval of the displacement, expressed algebraically, of this significant instant from an ideal instant. This displacement is considered positive when a significant instant occurs after the ideal instant. The degree of individual distortion is usually expressed as a percentage.

(c) Degree of Isochronous Distortion. Ratio to the unit interval of the maximum measured difference, irrespective of sign, between the actual and the theoretical intervals separating any two significant instants of modulation (or of restitution), these instants being not necessarily consecutive. The degree of distortion (of an isochronous modulation or restitution) is usually expressed as a percentage.

Note. The result of the measurement should be completed by an indication of the period, usually limited, of the observation. For a prolonged modulation (or restitution) it will be appropriate to consider the probability that an assigned value of the degree of distortion will be exceeded.

DISTORTION DELAY (of a transmission system). That distortion caused by the difference between the maximum transit time and the minimum transit time of frequencies within a specified band. (*Also called* Time Delay Distortion *and* Phase Distortion.)

DISTORTION, END (of start-stop teletypewriter signals). The shifting of the end of all marking pulses from their proper position in relation to the beginning of the start pulse.

DISTORTION, FORTUITOUS (of telegraph signals). Distortion resulting from causes generally subject to random laws, for example, accidental irregularities in the operating of the apparatus and moving parts, disturbances affecting the transmission channel, etc.

DISTORTION, INTERMODULATION. Nonlinear distortion characterized by the appearance of frequencies in the output, equal to the sums and differences of integral multiples of the component frequencies present in the input.

Note. Harmonic components also present in the output are usually not included as part of the intermodulation distortion. When harmonics are included, a statement to that effect should be made.

DISTORTION, NONLINEAR. Distortion caused by a deviation from a linear relationship between the input and output of a system or component.

DISTORTION, PHASE-COEFFICIENT. The difference between the maximum transit time and the minimum transit time for frequencies within a specified band. (*See* Distortion, Delay.)

DISTORTION, SINGLE-HARMONIC. The ratio of the power at the fundamental frequency, measured at the output of the transmission system considered, to the power of any single harmonic observed at the output of the system because of its nonlinearity, when a single frequency signal of specified power is applied to the input of the system; expressed in db.

DISTORTION, TELETYPEWRITER SIGNAL (of start-stop teletypewriter signals). The shifting of the transition points of the signal pulses from their proper positions relative to the beginning of the start pulse. The magnitude of the distortion is expressed in percent of a perfect unit pulse length.

DISTORTION, TOTAL HARMONIC. The ratio of the power at the fundamental frequency, measured at the output of the transmission system considered, to the power of all harmonics observed at the output of the system because of its nonlinearity, when a single frequency signal of specified power is applied to the input of the system; expressed in db.

DIVERSITY. That method of transmission and/or reception, whereby, in order to reduce the effects of fading, a single received information signal is derived from a combination of, or selection from, a plurality of signals containing the same information. Improvement gained shall be expressed in db.

DIVERSITY, DUAL. The term applied to the simultaneous combining of two signals and their detection through the use of space, frequency, or polarization characteristics.

DIVERSITY, FREQUENCY. Any method of transmission and reception wherein the same information signal is transmitted and received simultaneously on two or more distinct frequencies.

DIVERSITY, POLARIZATION. A method of transmission and/or reception of information accomplished by the use of separate vertically and horizontally polarized antennas.

DIVERSITY, QUADRUPLE. The term applied to the simultaneous combining of four signals and their detection through the use of space, frequency, or polarization characteristics or combinations thereof.

DIVERSITY, SPACE. Any method of transmission and/or reception which employs antennas having spatial separation.

DOPPLER EFFECT. The phenomenon evidenced by the change in the observed frequency of a wave in a transmission system caused by a time rate of change in the effective length of the path of travel between the source and the point of observation.

DOUBLE SIDEBAND TRANSMISSION. *See* Transmission, Double Sideband.

DUPLEX OPERATION. *See* Operation.

ECHO. The effect of a wave which, having been derived (for example by reflection) from a primary wave, arrives at either end of the same circuit with sufficient magnitude and delay to be distinctly recognized.

ECHO ATTENUATION. In a four-wire (or two-wire) circuit in which the two directions of transmission can be separated from each other, the attenuation, R_e, of the echo currents (which return to the input of the circuit under consideration) is determined by the ratio of the transmitted power, P_1, to the echo power received, P_2; expressed in db.

EFFECTIVE RADIATED POWER. *See* Transmitter Power Output Rating.

EFFICIENCY FACTOR, IN TIME (of a telegraph communication). The efficiency factor of a communication is the ratio of the time taken to transmit a text, automatically and at a specified modulation rate, to the time actually taken to receive the same text with a specified error rate.

Notes. (a) The whole of the apparatus comprising the communication is assumed to be in the normal conditions of adjustment and operation.
(b) A telegraph communication may have a different efficiency factor in time for the two directions of transmission.
(c) The practical conditions of measurement should be specified, in particular the duration.

EHF (EXTREMELY HIGH FREQUENCY). *See* Frequency Spectrum Designation.

ELECTRICALLY POWERED TELEPHONE. *See* Telephone Types.

ELF (EXTREMELY LOW FREQUENCY). *See* Frequency Spectrum Designation.

END DISTORTION. *See* Distortion, End.

END INSTRUMENT. A device which is connected to the terminal of a circuit and used to convert usable intelligence into electrical signals or vice-versa.

EQUALIZATION. The process of reducing frequency and/or phase distortion of a circuit by the introduction of networks to compensate for the difference in attenuation and/or time delay at the various frequencies in the transmission band.

ERRONEOUS BIT. *See* Bit.

ERRONEOUS BLOCK. A block in which there are one or more erroneous bits.

ERROR BURST. A group of bits in which two successive erroneous bits, are always separated by less than a given number (X) of correct bits.

Note. The last erroneous bit in a burst and the first erroneous bit in the following burst are accordingly separated by X correct bits or more. The number X should be specified when describing an error burst

ERROR-CORRECTING CODE. A code in which each telegraph or data signal conforms to specific rules of construction so that departures from this construction in the received signals can be automatically detected, and permits the automatic correction, at the receiving terminal, of some or all of the errors. Such codes require more signal elements than are necessary to convey the basic information.

ERROR-CORRECTING SYSTEM. A system employing an error-correcting code and so arranged that some or all signals detected as being in error are automatically corrected at the receiving terminal before delivery to the data sink or to the telegraph receiver.

ERROR-DETECTING CODE. A code in which each telegraph or data signal conforms to specific rules of construction, so that departures from this construction in the received signals can be automatically detected. Such codes require more signal elements than are necessary to convey the fundamental information.

ERROR-DETECTING SYSTEM. A system employing an error-detecting code and so arranged that any signal detected as being in error is—

(a) Either deleted from the data delivered to the data sink, in some cases with an indication that such deletion has taken place,

(b) Or delivered to the data sink together with an indication that it has been detected as being in error.

ERROR-DETECTING AND FEEDBACK SYSTEM (decision feedback system, request repeat system, ARQ system). A system employing an error-detecting code and so arranged that a signal detected as being in error automatically initiates a request for retransmission of the signal detected as being in error.

ERROR; SINGLE, DOUBLE, TRIPLE, . . . ETC. A group of 1, 2, 3, . . ., etc., consecutive erroneous bits, preceded and followed immediately by at least one correct bit.

ERROR RATE (bit, block, character, element). A ratio of the number of bits, elements, characters or blocks incorrectly received to the total number of bits, elements, characters or blocks sent.

ERROR-RATE, RESIDUAL (undetected error r[illegible] The ratio of the number of bits, elements, characters, blocks inc[illegible]y received but undetected or uncorrected by the error-control equipment, to the total number of bits, unit elements, characters, blocks sent.

EXALTED CARRIER RECEPTION. A method of receiving either amplitude or phase modulated signals in which the carrier is separated from the sidebands, filtered and amplified, and then combined with the sidebands again at a higher level prior to demodulation.

FACSIMILE. A line scanning system of telecommunication for the transmission of fixed images, with or without halftones, with a view to their reproduction in a permanent form. (Wirephoto and telephoto are facsimile through wire circuits; radio photo is facsimile via radio.) *See* Graphics.

FADING. The fluctuation in intensity of any or all frequency components of a received radio signal due to changes in the characteristics of the propagation path.

F DING, FLAT. The type of fading in which all frequency components of he received radio signal fluctuate in the same proportion simultaneously.

FADING, SELECTIVE. That type of fading in which the various frequency components of the received radio signal fluctuate independently.

FAULT. A malfunction that is reproducible, as contrasted to an error, which, is defined as a malfunction which is not reproducible. A malfunction is considered reproducible if it occurs consistently under the same circumstances.

FORMAT. Arrangement of bits or characters within a group, such as a word, message, or language; shape, size, and general makeup of a document.

FORTUITOUS DISTORTION. *See* Distortion, Fortuitous.

FREQUENCY.

(a) Assigned Frequency. The frequency of the center of the radiated bandwidth shall be designated the "assigned frequency." (The frequency of the RF carrier, whether suppressed or radiated, shall be referred to in parentheses following the assigned frequency and shall be the frequency appearing on the dial settings of RF equipments intended for a single sideband or independent sideband.)

(b) Carrier Frequency. The frequency of the unmodulated carrier.

(c) Characteristic Frequency. A frequency which can be easily identified and measured in a given emission.

(d) Reference Frequency. A frequency having a fixed and specified position with respect to the assigned frequency. This displacement of this frequency with respect to the assigned frequency has the same absolute value and sign that the displacement of the characteristic frequency has with respect to the center of the frequency band occupied by the emission.

(e) Frequency Tolerance. The maximum permissible departure by the the center frequency of the frequency band occupied by an emission from the assigned frequency or by the characteristic frequency of an emission from the reference frequency. The frequency tolerance is expressed in parts in 10^6 or in cycles per second.

FREQUENCY-CHANGE SIGNALING. A signaling method in which one or more particular frequencies correspond to each desired signaling condition of a code. The transition from one set of frequencies to the other may be either a continuous or a discontinuous change in frequency or in phase

(a) Frequency-Exchange Signaling Two-Source Frequency Keying. A frequency-change signaling method in which the change from one signaling condition to another is accompanied by decay in amplitude of one or more frequencies and by buildup in amplitude of one or more other frequencies.

(b) Frequency Shift Keying, Frequency Shift Signaling (FSK). A frequency-change signaling method in which the frequency or frequencies are varied in accordance with the signals to be transmitted and characterized by continuity of phase during the transition from one signaling condition to another

FREQUENCY DIVERSITY. *See* Diversity, Frequency.

FREQUENCY MODULATION. *See* Modulation, Frequency.

FREQUENCY SPECTRUM DESIGNATION.

	kc	*mc*	*gc (kmc)*	*ITU Band*
ELF (extremely low frequency)	below 0.3	------------	-----	--
ILF (infra low frequency)	0.3–3	------------	-----	--
VLF (very low frequency)	3–30	------------	-----	4
LF (low frequency)	30–300	.03–0.3	-----	5
MF (medium frequency)	300–3,000	0.3–3	-----	6
HF (high frequency)	3,000–30,000	3–30	-----	7
VHF (very high frequency)	----------	30–300	.03–0.3	8
UHF (ultra high frequency)	----------	300–3,000	0.3–3	9
SHF (super high frequency)	----------	3,000–30,000	3–30	10
EHF (extremely high frequency)	----------	30,000–300,000	30–300	11

Note: Gigacycles (gc) and kilomegacycles (kmc) are synonymous.

FREQUENCY TOLERANCE. *See* Frequency.

FULL DUPLEX. *See* Operation.

GAIN (TRANSMISSION GAIN). The action by which, or the result in which, the power of an electrical signal is increased; expressed in db.

GRAPHICS. A method of transmitting visual intelligence via electromagnetic means that is received at the far end in a permanent form. (The term graphics is a broader term than facsimile. Facsimile, however, is a form of graphics.)

GROUP. *See* Wideband System.

GUARD BAND. A frequency band between two channels which gives a margin of safety against mutual interference.

HALF DUPLEX. *See* Operation.

HF (HIGH FREQUENCY). *See* Frequency Spectrum Designation.

HIGH PERFORMANCE EQUIPMENTS. Those equipments having sufficiently exacting characteristics to permit their use in trunk or link circuits. (Note: Requirements for global and tactical high performance equipments may differ.)

ILF (INFRA LOW FREQUENCY). *See* Frequency Spectrum Designation.

IMPEDANCE, TERMINAL. *See* Terminal Impedance.

INDEPENDENT SIDEBAND TRANSMISSION. *See* Transmission, Independent Sideband.

INDEX OF COOPERATION—DIAMETRAL OR INTERNATIONAL (FACSIMILE). The product of the drum diameter and the line advance in scanning lines per unit length. The unit length must be the same as that used for expressing the drum diameter.

INFORMATION BITS. *See* Bit.

INFORMATION TRANSFER (User). The final result of a data transmission from a data source to a data sink. The information transfer rate may or may not be equal to the transmission modulation rate.

INPUT-OUTPUT DEVICE. Any equipment which introduces data into or extracts data from a data communications system.

INSERTION GAIN. The insertion gain of a transmission system (or component thereof) inserted between two impedances Z_t (transmitter) and Z_r (receiver) is the ratio of the power measured at the receiver Z_r after insertion, of the transmission system considered, to the power measured before insertion; expressed in db. If the resulting number in db thus obtained is negative, an insertion loss is indicated.

INSERTION LOSS. The insertion loss of a transmission system (or component thereof) inserted between two impedances Z_t (transmitter) and Z_r (receiver) is the ratio of the power measured at the receiver Z_r, before insertion of the transmission system considered, to the power measured after insertion; expressed in db. If the resulting number in db thus obtained is negative, an insertion gain is indicated.

INTERFACE. A concept involving the specification of the interconnection between two equipments or systems. The specification includes the type, quantity and function of the interconnection circuits and the type and form of signals to be interchanged via those circuits.

INTERNAL BIAS (TELETYPEWRITER). That bias, either marking or spacing, that may occur within a start-stop teletypewriter receiving mechanism and which will have the same effect on the margins of operation as bias external to the receiver.

ISOCHRONOUS MODULATION. *See* Modulation, Isochronous.

LF (LOW FREQUENCY). *See* Frequency Spectrum Designation.

LIMITER. A device which reduces the power of an electrical signal when it exceeds a specified value. The amount of reduction or compression increases with increase of the input power.

LINE SIDE. That portion of a device which looks toward the transmission path (line circuit, loop, trunk).

LINK.

(a) A portion of a communication circuit.

(b) A channel or circuit designed to be connected in tandem with other channels or circuits.

(c) A radio path between two points, called a radio link; the resultant circuit may be unidirectional, half duplex, or duplex.

Note. The term "link" should be defined or qualified when used. It is generally accepted that the signals at each end of a link are in the same form.

LOCAL LINE. *See* Loop.

LOCAL SIDE. That portion of a device which looks toward the internal station facilities.

LOOP. A loop is a single message circuit from a switching center and/or individual message distribution point to the terminals of an end instrument.

(a) Line Loop. The portion of a radio or wire circuit that connects a user's end instrument and a central office. (Synonymous terms are "local line" and "user's line.")

LOW PERFORMANCE EQUIPMENTS. Those equipments having insufficiently exacting characteristics to permit their use in trunk of link circuits. Such equipments may be employed in loop circuits whenever they meet loop circuit requirements.

MARKING PULSE. *See* Pulse, Marking.

MASTER GROUP. *See* Wideband System.

MESSAGE. A communication from a source to one or more destinations in a suitable language.

MESSAGE SWITCHING. *See* Switching, Message.

MF (MEDIUM FREQUENCY). *See* Frequency Spectrum Designation.

MODEM. Acronym for modulator-demodulator.

MODULATION. The process of varying some characteristics of the carrier wave in accordance with the instantaneous value, or samples, of the intelligence to be transmitted *See also* Carrier.

MODULATION, AMPLITUDE (AM). The form of modulation in which the amplitude of the carrier is varied in accordance with the instantaneous value of the modulating signal.

MODULATION, DIFFERENTIAL. A type of modulation in which the choice of the significant condition for any signal element is dependent on the choice for the previous signal element. Delta modulation is an example

MODULATION, FREQUENCY (FM). The form of modulation in which the instantaneous frequency of a sine wave carrier is caused to depart from the carrier frequency by an amount proportional to the instantaneous value of the modulating signal.

MODULATION, ISOCHRONOUS. Modulation (or demodulation) in which the time interval separating any two significant instants is theoretically equal to the unit interval or to a multiple of this.

MODULATION, PHASE (PM). The form of modulation in which the angle relative to the unmodulated carrier angle is varied in accordance with the instantaneous value of the amplitude of the modulating signal.

MODULATION, PULSE AMPLITUDE (PAM). The form of modulation in which the amplitude of the pulse carrier is varied in accordance with successive samples of the modulating signal.

MODULATION, PULSE CODE (PCM). The form of modulation in which the modulating signal is sampled, and the sample quantised and coded so that each element of information consists of different kinds and/or number of pulses and spaces.

MODULATION, PULSE FREQUENCY (PFM). The form of modulation in which the pulse repetition frequency of the carrier is varied in accordance with successive samples of the modulating signal.

MODULATION, PULSE TIME (PTM). The form of modulation in which the time of occurrence of some characteristics of the pulse carrier is varied in accordance with successive samples of the modulating signal. (This includes pulse position and pulse duration or pulse width modulation.)

MODULATION RATE. Reciprocal of the unit interval measured in seconds. (This rate is expressed in bauds.)

MODULATION WITH A FIXED REFERENCE. A type of modulation in which the choice of the significant condition for any signal element is based on a fixed reference.

NECESSARY BANDWIDTH. *See* Bandwidth, Occupied.

NODE. *Also called* Junction Point, Branch Point, *or* Vertex. A terminal of any branch of a network or a terminal common to two or more branches of a network.

NOISE, INTERMODULATION (Radio System). In a transmission path or device, that noise which is contingent upon modulation and results from any nonlinear characteristic in the path or device.

of 144-line, 144-receiver, or C-message weighting, or flat weighting, shall be indicated in parentheses as required. *See* Noise Weighting.

Notes. (1) With C-message weighting, a 1 milliwatt, 1,000 cps tone will read +90 dbrn, but the same power as white noise, randomly distributed over a 3-kc band (nominally 300 to 3,300 cps) will read approximately +88.5 dbrn (rounded off to +89 dbrn), due to the frequency weighting.

(2) With 144 weightings, a 1 milliwatt, 1,000 cps tone will also read +90 dbrn, but the same 3-kc white noise power will read only +82 dbrn, due to the different frequency weighting.

(l) dbrn (144-line). Weighted circuit noise power in dbrn, measured on a line by a noise measuring set with 144-line weighting. *See* Noise Weighting.

(m) dbrn (144-receiver). Weighted circuit noise power in dbrn, measured across the receiver of a subset with No. 144-receiver, by a noise measuring set with 144-receiver weighting. *See* Noise Weighting.

(n) dbrn (C-message). Weighted circuit noise power in dbrn, measured on a line by a noise measuring set with C-message weighting. *See* Noise Weighting.

(o) dbrn (f_1-f_2). Flat noise power in dbrn, measured over the frequency band between frequencies f_1 and f_2. *See* Noise Weighting (Flat Weighting).

(p) PSOPHOMETRIC VOLTAGE, *or* "Psophometric p.d." Circuit noise voltage measured on a line with a Psophometer which includes a CCIF-1951 weighting network. *See* Noise Weighting.

Notes. (1) Do not confuse with "psophometric emf," conceived of as the emf in a generator (or line) with 600 ohms internal resistance, and hence, for practical purpose numerically double the corresponding psophometric voltage.

(2) Psophometric voltage readings are commonly converted to dbm (psoph) by the relation:

$$\text{dbm (psoph} = 20 \log_{10} V - 57.78 \text{ (V in psophometric millivolts)),}$$

(q) pw. Picowatt, equal to 10^{-12} watt, or −90 dbm. A unit of absolute power commonly used for both weighted and unweighted noise. Context must be observed.

Note. Conversion relations: $10 \log_{10} pw = dbm - 90$.

(r) pwp. pw, psophometrically weighted. *See* pw, *and* Noise Weighting.

NOISE WEIGHTING. In measurement of circuit noise, a specific amplitude-frequency characteristic of a noise measuring set, designed to give numerical readings which approximate the amount of transmission impairment due to the noise, to an average listener using a particular class of telephone subset.

Note. The noise weightings generally used were established by agencies concerned with public telephone service, and are based on characteristics of specific commercial telephone subsets, representing successive stages of technological development. The coding of commercial apparatus appears in the nomenclature of certain weightings. The same weighting nomenclature and units are used in military versions of commercial noise measuring sets.

(a) 144-Line Weighting. A noise weighting used in a noise measuring set to measure noise on a line that would be terminated by a subset with No. 144-receiver, or a similar subset. The meter scale readings are in dbrn (144-line).

Note. This type of subset, deskstand with hand receiver, is obsolete.

(b) 144-Receiver Weighting. A noise weighting used in a noise measuring set to measure noise across the receiver of a subset equipped with No. 144-receiver. The meter scale readings are in dbrn (144-receiver).

Note. This type of subset, deskstand with hand receiver, is obsolete.

(c) F1A-Line Weighting. A noise weighting used in a noise measuring set to measure on a line that would be terminated by a 302-type or similar subset. The meter scale readings are in dba (F1A).

(d) HA1-Receiver Weighting. A noise weighting used in a noise measuring set to measure noise across the HA1-receiver of a 302-type or similar subset. The meter scale readings are in dba (HA1).

(e) C-Message Weighting. A noise weighting used in a noise measuring set to measure noise on a line that would be terminated by a 500 type or similar subset. The meter scale readings are in dbrn (C-message).

(f) Flat Weighting. A noise measuring set amplitude-frequency characteristic which is flat over a specified frequency range, which must be stated. Flat noise power may be expressed in dbrn ($f_1 - f_2$), or in dbm ($f_1 - f_2$). The terms 3-kc Flat Weighting, and 15-kc Flat Weighting are also used, for characteristics flat from 30 cps to the upper frequency indicated.

(g) Psophometric Weighting. A noise weighting established by the International Consultative Committee for Telephony (CCIF, now CCITT), designated as CCIF–1951 weighting, for use in a noise measuring set or "Psophometer." The shape of this characteristic is virtually identical to that of F1A weighting. The Psophometer is, however, calibrated with a tone of 800 cps, 0 dbm, so that the corresponding voltage across 600 ohms produces a reading called 0.775 volt. This introduces a 1 db adjustment in the formulas for conversion with dba. *See* Noise Measurement Units, dbm psophometrically weighted.

NOISE LEVEL, CARRIER. *See* Carrier Noise Level.

NOMINAL BANDWIDTH. *See* Bandwidth, Occupied.

OCCUPIED BANDWIDTH. *See* Bandwidth, Occupied.

ONE-WAY REVERSIBLE. *See* Operation.

OPEN-CIRCUIT WORKING. A method of single current operation in which no current flows in the circuit while the transmitting device is at rest.

OPERATION.

(a) Broadcast. That type of operation in which a transmitting point emits information which may be received by one or more stations.

(b) Conference. A form of simplex operation in which a number of stations may simultaneously exchange information carry on conversations, or pass messages among themselves.

(c) Duplex (Full Duplex). A type of operation in which simultaneous two-way conversations, messages, or information may be passed between any two or more given points.

(d) Half-Duplex (Single Telegraph Operation). A circuit designed for duplex operation, but which on account of the nature of the terminal equipments can be operated alternately only.

(e) One-Way Reversible. Similar to half-duplex operation.

(f) Push-to-Talk (Press-To-Talk). *See* Simplex.

(g) Simplex. That type of operation which permits the transmission of signals in either direction alternately.

(h) Speech-Plus-Duplex (or Simplex). A method of operation in which speech and telegraphy are transmitted simultaneously over the same circuit.

(i) Unidirectional (Send Only) (Receive Only). A method of operation between terminals one of which is a transmitter and the other a receiver.

ORDER WIRE. (*Also called* Service Wire, Engineering Circuit, *or* Speaker Circuit.) A circuit for use by maintenance personnel for communications incident to lineup and maintenance of communication facilities.

OUTPUT RATING. *See* Transmitter Power Output Rating.

OVERHEAD BITS. *See* Bits.

PEAK ENVELOPE POWER. *See* Transmitter Power Output Rating.

PHASE DISTORTION. *See* Distortion, Delay.

PHASE DISTORTION COEFFICIENT. *See* Distortion, Phase Coefficient.

PHASE MODULATION. *See* Modulation, Phase.

PILOT (in a transmission system). A signal wave, usually a single frequency, transmitted over the system and used for either level control, synchronization, or both.

POLARIZATION DIVERSITY. *See* Diversity, Polarization.

PROGRAMMER. That part of digital apparatus having the function of controlling the timing and sequencing of operations or a person who prepares sequences of instructions for a computer.

PSOPHOMETRIC VOLTAGE. *See* Noise.

PULSE. A signal characterized by the rise and decay in time of a quantity whose value is normally constant.

PULSE AMPLITUDE MODULATION. *See* Modulation, Pulse Amplitude

PULSE CODE MODULATION. *See* Modulation, Pulse Code.

PULSE DECAY TIME. The time required for the instantaneous amplitude to go from 90 percent to 10 percent of the peak value.

PULSE FREQUENCY MODULATION. *See* Modulation, Pulse Frequency.

PULSE, MARKING, TELETYPEWRITER. That significant condition of a modulation which results in an active selecting operation in a receiving apparatus. *See* Significant Condition.

PULSE RISE TIME. The time required for the instantaneous amplitude to go from 10 percent to 90 percent of the peak value.

PULSE, SPACING, TELETYPEWRITER. That significant condition of a modulation which results in a passive selecting operation in a receiving apparatus. *See* Significant Condition of a Modulation.

PULSE TIME MODULATION. *See* Modulation, Pulse time.

PUSH-TO-TALK. *See* Operation.

pw. *See* Noise.

pwp. *See* Noise.

QUASI-ANALOG SIGNAL. A quasi-analog signal is a digital signal, after conversion to a form suitable for transmission over a specified analog channel. The specification of an analog channel would include frequency range, frequency bandwidth, S/N ratio, and envelope delay distortion. When this form of signaling is used to convey message traffic over dialed up telephone systems it is often referred to as voice-data.

REDUNDANT CODE. A code using more signal elements than necessary to represent the intrinsic information. For example:

(a) A five-unit code using all the characters of International Telegraph Alphabet No. 2 is not redundant.

(b) A five-unit code using the digits only in International Telegraph Alphabet No. 2 is redundant.

(c) A seven-unit code using only signals made of 4 "space" and 3 "mark" is redundant.

(d) An eight-unit code using one of the bits for parity is redundant.

REFERENCE LEVEL, SINGLE SIDEBAND EQUIPMENT. (Voice Frequency Input Power to a Transmitter, one Sideband Only.) The power of one or two equal tones which together cause the transmitter to develop its full rated power output.

REFLECTION COEFFICIENT

(a) The reflection coefficient at the junction of a uniform transmission line and a mismatched terminating impedance is the vector ratio of the electric field associated with the reflected wave to that associated with the incident wave.

(b) At any specified plane in a uniform transmission line between a source of power and an absorber of power, the reflection coefficient is the vector ratio of the electric field associated with the reflected wave to that associated with the incident wave. It is given by the formula:

$$(Z_2 - Z_1)/(Z_2 + Z_1)$$

where Z_1 is the impedance of the source and Z_2 is the impedance of the load.

RELATIVE TRANSMISSION LEVEL. The ratio of the test tone power at any point in a transmission system to the test tone power at some point in the system chosen as a reference point. The ratio shall be expressed in db. The transmission level at the transmitting switchboard is frequently taken as the zero level reference point. *See* Zero Transmission Level Reference Point.

REMOTE CONTROL EQUIPMENT. The apparatus used for performing, monitoring, supervising, or a combination of these, a prescribed function or functions at a distance by electrical means.

REPEATER. A device which amplifies or reshapes and/or retimes an input signal for further retransmission.

(a) Broadcast Repeater. A repeater connecting several channels, one incoming and the other outgoing.

(b) Conference Repeater. A repeater connecting several circuits, which receives telegraph signals from any one of the circuits and automatically retransmits them over all the others.

(c) Regenerative Repeater. A repeater in which the signals retransmitted are reshaped and retimed.

RESTITUTION (Demodulation). Series of significant conditions determined by the decisions taken according to the products of the demodulation process.

RETURN LOSS. The return loss at the junction of a transmission line and a terminating impedance is the ratio, expressed in db, of the reflected wave to the incident wave. More broadly, the return loss is a measure of the dissimilarity between two impedances, being equal to the number of decibels which corresponds to the scalar value of the reciprocal of the reflection coefficient, and hence being expressed by the formula:

$$20 \log_{10} \left| \frac{Z_1 + Z_2}{Z_1 - Z_2} \right| \text{db}$$

where Z_1 and Z_2 are the two impedances.

RF BANDWIDTH. *See* Bandwidth, Occupied.

SELECTIVE FADING. *See* Fading, Selective.

SERVICE BITS. *See* Bits.

SHF (SUPER HIGH FREQUENCY). *See* Frequency Spectrum Designation.

SIDEBANDS. The spectral energy distributed above and below a carrier resulting from a modulation process.

SIGNAL ELEMENT. Each of the parts constituting a telegraph or data signal and distinguished from the others by its nature, magnitude, duration and relative position (or by one or some of these features only).

SIGNALING, COMMON BATTERY. A method of actuating a line or supervisory signal at the distant end of a telephone line by the closure of a dc circuit.

SIGNAL CONVERTER. A device in which the input and output signals are formed according to the same code, but not according to the same type of electrical modulation.

SIGNALING, INBAND. Signaling which utilizes frequencies within the voice or intelligence band of a channel.

SIGNALING, OUT-OF-BAND. Signaling which utilizes frequencies within the guard band between channels. This term is also used to indicate the use of a portion of the channel bandwidth provided by the medium such as the carrier channel, but denied to the speech or intelligence path by filters. It results in a reduction of the effective available bandwidth.

SIGNALING, RINGDOWN. The application of signal to the line for the purpose of bringing in a line signal or supervisory signal at a switchboard or ringing a user's instrument. (Historically, this was a low frequency (about 20 cps) signal from the user on the line for calling the operator or for disconnect.)

SIGNIFICANT CONDITION OF A MODULATION. A condition assumed by the appropriate device corresponding to the quantized value (or values) of the characteristic (or characteristics) chosen to form the modulation. The following equivalent designations are used to identify the significant conditions for binary modulation:

Passive Frequency high	*Active Frequency high*
A	Z
0	1
Current Off	Current On
Tone Off	Tone On
Space	Mark
−	+
No Hole (paper tape)	Hole (paper tape)

SIGNIFICANT INSTANTS. The instants at which the successive significant conditions recognized by the appropriate device of the modulation or restitution begin. Each of these instants is determined as soon as the appropriate device takes up the significant condition usable for a recording or a processing.

SIGNIFICANT INTERVAL. Time interval between two consecutive significant instants.

SIMPLEX. *See* Operation.

SINGLE-HARMONIC DISTORTION. *See* Distortion, Single-harmonic.

SINGLE SIDEBAND TRANSMISSION. *See* Transmission, Single Sideband.

SKEW (FACSIMILE). The deviation of the received frame from the rectangularity due to asynchronism between scanner and recorder.

SOUND-POWERED TELEPHONE. *See* Telephone Types.

SPACE DIVERSITY. *See* Diversity, Space.

SPACING PULSE. *See* Pulse, Spacing.

SPEECH PLUS DUPLEX. *See* Operation.

STANDARD TEST TONE. For use at the 600 ohms audio portions of a circuit; shall be one mw (0 dbm) with a frequency of 1,000 cps, and shall be applied at a zero transmission level reference point. (If applied to a point with a relative level other than zero, the absolute power of the tone shall be adjusted to suit the relative level at the point of application.)

STORE-AND-FORWARD. *See* Switching, Message.

SUBCARRIER. A carrier which is applied as modulation on another carrier, or on an intermediate subcarrier. *See also* Carrier.

SUPERGROUP. *See* Wideband System.

SUPPRESSED CARRIER TRANSMISSION. *See* Transmission, Suppressed Carrier.

SWITCHING CENTER. (*Also called* Switching Facility, Switching Exchange, *or* Central Office.) An installation in a communication system in which switching equipment is used to interconnect communication circuits on a message or circuit switching basis.

SWITCHING CIRCUIT. The term applied to the method of handling traffic through a switching center, either from local users, or from other switching centers, whereby a distant electrical connection is established between the calling and called stations.

SWITCHING, MESSAGE. The term applied to any indirect or store-and-forward traffic through a switching center, either from local users or from other switching centers. Message switching, or store-and-forward, is the technique whereby messages are transmitted link by link through the communication network of switching centers.

SYSTEM STANDARDS.

(a) The minimum required electrical performance characteristics of communication circuits which are based on measured performance of developed circuits under the various operating conditions for which the circuits were designed.

(b) The specified characteristics not dictated by electrical performance requirements but necessary in order to permit interoperation. (For example, the values for center frequencies for telegraph channels, test tone, etc.) *See also* Designed Objectives.

SYSTEM, SYNCHRONOUS, A system in which the sending and receiving instruments are operating continuously at substantially the same frequency and are maintained, by means of correction if necessary, in a desired phase relationship.

TELECOMMUNICATIONS. Any transmission, emission, or reception of signs, signals, writings, images, and sounds or intelligence of any nature by wire, radio, visual or other electromagnetic means.

TELEPHONE TYPES.

(a) Electrically-powered Telephone. A telephone in which the operating power is obtained either from batteries located at the telephone (local battery) or from a telephone central office (common battery).

(b) Sound-powered Telephone. A telephone in which the operating power is derived from the speech input only.

TERMINAL IMPEDANCE. The complex inpedance as seen at the unloaded output or input terminals of a transmission equipment or line which is otherwise in normal operating condition.

TEST-TONE, STANDARD. *See* Standard Test-tone.

TOTAL-HARMONIC DISTORTION. *See* Distortion, Total-harmonic.

TRANSITION, SIGNAL. The change from one signaling condition to another; for example, the change from "mark" to "space" or from "space" to "mark." *See also* Pulse, Marking *and* Pulse, Spacing.

TRANSMISSION, ASYNCHRONOUS. A transmission process such that between any two significant instants in the same group,* there is always an integral number of unit intervals. Between two significant instants located in different groups, there is not always an integral number of unit intervals.

TRANSMISSION, DOUBLE-CURRENT (POLAR DIRECT-CURRENT SYSTEM). A form of binary telegraph transmission in which positive and negative direct currents denote the significant conditions.

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*In data transmission this group is a block or a character
In telegraphy this group is a character

TRANSMISSION, DOUBLE SIDEBAND. That method of communication in which the frequencies produced by the process of amplitude modulation are symmetrically spaced both above and below the carrier frequency and are all transmitted; this is conventional AM.

TRANSMISSION, INDEPENDENT SIDEBAND (TWIN SIDEBAND). That method of communication in which the frequencies produced by the process of amplitude modulation on opposite sides of the carrier are not related to each other, but are related separately to two sets of modulating signals. The carrier frequency may be either transmitted or suppressed.

TRANSMISSION, PARALLEL (COINCIDENT TRANSMISSION). The simultaneous transmission of a certian number of signal elements. For example: Use of a code according to which each signal is characterized by a combination of 3 out of 12 frequencies simultaneoulsy transmitted over the channel.

TRANSMISSION, SERIAL (SEQUENTIAL TRANSMISSION). Transmission at successive intervals of signal elements constituting a data or telegraph signal.

Note. The sequential elements may be transmitted with or without interruption, provided that they are not transmitted simultaneously.

TRANSMISSION, SINGLE-CURRENT (NEUTRAL DIRECT-CURRENT SYSTEM). A form of telegraph transmission effected by means of unidirectional currents.

TRANSMISSION, SINGLE SIDEBAND. That method of communication in which the frequencies produced by the process of amplitude modulation on one side of the carrier are transmitted and those on the other side are suppressed. The carrier frequency may be either transmitted or suppressed.

TRANSMISSION, SUPPRESSED OR REDUCED CARRIER. That method of communication in which the carrier frequency is suppressed either partially or to the maximum degree possible. One or both of the sidebands may be transmitted.

(a) Transmission, Double Sideband Suppressed Carrier. That method of communication in which the frequencies produced by the process of amplitude modulation are symmetrically spaced both above and below the carrier. The carrier level is suppressed to a value of at least 45 db below the level of the transmitted sidebands.

TRANSMISSION, SYNCHRONOUS. A transmission process such that between any two significant instants in the overall stream, there is always an integral number of unit intervals.

TRANSMISSION, VESTIGIAL SIDEBAND. That method of communication in which frequencies of one sideband, the carrier, and only a portion of the other sideband are transmitted.

TRANSMITTER POWER OUTPUT RATING.

(a) Whenever the power of a radio transmitter, etc. is referred to, it shall be expressed in one of the following forms:

(1) Peak envelope power (pp), sometimes abbreviated (pep).

(2) Mean power (pm).

(3) Carrier power (pc).

(b) For different classes of emission, the relationships between peak envelope power, mean power, and the carrier power are defined as follows:

(1) Peak Envelope Power of a Radio Transmitter: The power supplied to the antenna transmission line by a transmitter during one radio frequency cycle at the highest crest of the modulation envelope, taken under conditions of normal operation.

(2) Mean Power of a Radio Transmitter: The power supplied to the antenna transmission line by a transmitter during normal operation, averaged over a time sufficiently long compared with the period of the lowest frequency encountered in the modulation A time of one-tenth second during which the mean power is greatest will be selected normally.

(3) Carrier Power of a Radio Transmitter: The average power supplied to the antenna transmission line by a transmitter during one radio frequency cycle under conditions of no modulation. This definition does not apply to pulse modulated emissions.

(4) Effective Radiated Power: The power supplied to the antenna multiplied by the relative gain of the antenna in a given direction.

TRANSPOSITION (data or telegraph transmission). A transmission defect in which, during one character period, one or more signal elements are changed from one significant condition to the other, and an equal number of elements are changed in the opposite sense.

TWO-TONE TELEGRAPH, TWO-TONE KEYING. A system employing a transmission path comprising two channels in the same direction, one for transmission of the space elements of a binary modulation, the other for transmitting the mark elements of the same modulation.

UHF (ULTRA HIGH FREQUENCY). *See* Frequency Spectrum Designation.

UNIDIRECTIONAL. *See* Operation.

UNIT INTERVAL. In a system using an equal-length code or in a system during isochronous modulation (or demodulation), it is the interval of time such that the theoretical duration of the significant intervals of a telegraph modulation are all whole multiples of this interval.

USER'S LINE. *See* Loop.

VESTIGIAL SIDEBAND TRANSMISSION. *See* Transmission, Vestigial Sideband.

VHF (VERY HIGH FREQUENCY). *See* Frequency Spectrum Designation

VLF (VERY LOW FREQUENCY). *See* Frequency Spectrum Designation.

vu. Volume unit, the unit of measurement for electrical speech power in communication work as measured by a vu meter in the prescribed manner. The vu meter is a volume indicator in accordance with American Standards Association c 16.5-1942. It has a db scale and specified dynamic and other characteristics in order to obtain correlated readings of speech power necessitated by the rapid fluctuation in level of voice currents. Zero vu equals zero dbm in measurement of sine wave test tone power.

WEIGHTING. *See* Noise.

WIDEBAND SYSTEM. A system with a multichannel bandwidth of 20 kc or more. (*Also called* Broadband System.)

(a) GROUP. A subdivision containing a number of voice channels, either within a supergroup or separately, normally comprised of up to 12-voice channels occupying the frequency band 60-108 kc. Each voice channel may be multiplexed for teletypewriter operation, if required.

(b) SUPERGROUP. Normally 60-voice channels of a wideband path or five groups of 12-voice channels each and occupying the frequency band 312-522 kc.

(c) MASTER GROUP. Supergroups 4 to 8 form the basic master group which occupies the frequency band 60-2,540 kc.

WORD (TELEGRAPH). By definition a telegraph word shall consist of six-character intevals when computing traffic capacity in words per minute.

$$\text{wpm} = \frac{\text{Mod rate} \times 10}{\text{Units per character interval}}$$

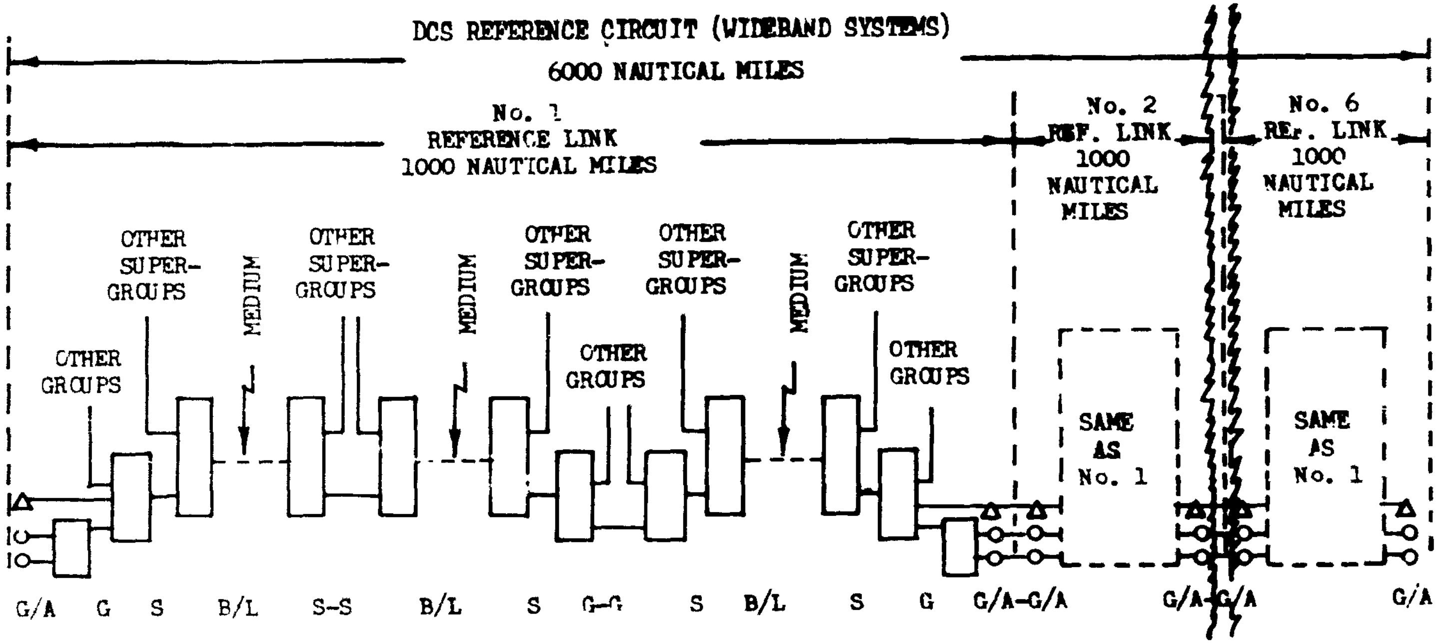
ZERO TRANSMISSION LEVEL REFERENCE POINT. An arbitrarily chosen point in a circuit to which all relative transmission levels are referred. The transmission level at the transmitting switchboard is frequently taken as the zero transmission level reference point. *See also* Relative Transmission Level.

CHAPTER III

GLOBAL COMMUNICATIONS

3.2 Global Transmission Systems

3.2.1 *General.* DCS Reference Circuit (Wideband Systems): The DCS Reference Circuit for Wideband Systems is a four-wire, nominal 4-kc telephone type circuit, 6,000 nautical miles long, for the transmission of telephone, teletypewriter, graphic and data communications signals and control signals. The composition of the DCS Reference Circuit (Wideband Systems) is shown in figure 3.2.1. It consists of six links, each nominally 1,000 nautical miles long, interconnected on a four-wire basis at audio frequency. Each has three sections nominally 333 nm long, consisting of wire or radio facilities with intermediate repeaters, as required, and equipped with frequency division multiplex equipment.



A--Audio Frequency Four-wire Nominal 4-kc Circuit
G—Basic Group Frequency Band, 60-108 kc
S—Basic Supergroup Frequency Band 312-552 kc
B—Baseband Frequencies for Radio Relay Transmission
L--Line Frequency Band for Cable Transmission
○—Access Point, Nominal 4-kc Circuit
△—Access Point, Nominal 48-kc Circuit (through group or high speed data modem)

Figure 3.2.1 DCS Reference Circuit—Transmission Subsystem, Nominal 4-kc & 48-kc channels.

3.2.2.4 *Tropospheric Scatter Systems.*

3.2.2.4.1 *DSC Reference Circuit (Tropospheric Scatter).* The composition of the DCS Tropospheric Scatter Reference Circuit coincides with that of the DCS Wideband Reference Circuit described in paragraph 3.2.1. The DCS Tropospheric Scatter Reference Circuit is further described in the following paragraphs in terms of its transfer functions and interface parameters. Actual tropospheric scatter circuits which are a part of the DCS shall be designed to have these transfer functions and interface parameters.

3.2.2.4.1.1 *Transfer Function Parameters.* The transfer function parameters define the properties of the DCS Tropospheric Reference Circuit in terms of circuits utilizing 4-kc channel allocations involving the various distortions, noise, stability, adjustment, and signal level loading. As indicated in table 3.2.2.4.1.1, the parameters may be defined within three aspects: overall reference circuit, transmission medium (including repeaters), and multiplex equipment (for one nominal 1,000 nm link).

3.2.2.4.1.1.1 *Insertion Loss vs. Frequency.* The response characteristics are stated in terms of insertion loss referred to the 1,000 cps loss. Thus, a positive figure denotes lower response, and a negative figure indicates a higher response relative to 1,000 cps.

Table 3.2.2.4.1.1. Transmission Specifications for DCS Reference Circuit Transfer Function

Parameter	Overall reference circuit 6,000 nm (6 links)	Normally assignable to— Transmission medium, including repeaters (6 links)	Multiplex equipment (1 link only)	
Insertion loss-frequency, ref. to 1,000 cps:				
600–1,400 cps	+4.0−4.0 db		+0.7−0.7 db	
400–3,000 cps	+9.0−4.0 db		+1.5−0.7 db	
300–3,400 cps	+18.0−4.0 db		+3.0−0.7 db	
Envelope delay distortion, 1,000–2,600 cps max	1,000 μsec		160 μsec	
Median noise level, from all sources, during time block 2:			*Term only*	*Term & intermdiate*
Psophometrically weighted at OTLP, pwp	25,000	20,000	475	815
Equiv. white noise, F1A line wtg, dbaO	38.0	37.0	20.8	23.1
Harmonic distortion			−40 dbmO	
Gain change for output level increase from 0 dbmO, to— +3.5 dbmO			0.35 db max	
Gain change for output level increase from 0 dbmO, to— +12.0 dbmO			6.0 db min	
Net loss variation, max at 1,000 cps audio, or at any baseband frequency	±2.0 db	±0.5 db	±0.2 db	
Level adjustability		±0.5 db	±0.5 db	
Max. overall change in any audio freq.	±2 cps		±2 cps	
Stability of multiplex frequency generator. Initial setting to—			2 parts in 10^6	
Stability of multiplex frequency generator. Drift per month			2 parts in 10^7	
Single tone interference	24 dbaO			
Max. data/telegraph levels, single channel high speed.			(FSK)—13 dbmO	
			(AM)—10 dbmO	
Speech level			—15 dbmO	

Notes: 1. The noise power shall be divided such that 5,000 pwp is assigned to the multiplex equipment and 20,000 pwp to the transmission media.

2. The allowable transmission media noise in a section of length L nautical miles (L less than the 6,000-nautical mile reference circuit) is found by—

$$\text{Noise} = \frac{L}{6{,}000} \times 20{,}000 \text{ pwp}$$

3. The total noise shall not exceed 316,000 pwp (49 dbaO) 1-minute mean value more than a cumulative 0.1 percent during time block 2; see par. 3.2.2.4.1.1.3.

Single Link Channel Frequency Response

The frequency response referred to 1,000 cps for the multiplex equipment (1 link only) shall be as follows:

600–2,400 cps	+0.7	−0.7 db
400–3,000 cps	+1.5	−0.7 db
300–3,400 cps	+3.0	−0.7 db

Overall Circuit Frequency Response

The frequency response referred to 1,000 cps for the overall 6,000-nautical mile circuit shall be as follows:

600–2,400 cps	+4.0	−4.0 db
400–3,000 cps	+9.0	−4.0 db
300–3,400 cps	+18.0	−4.0 db

3.2.2.4.1.1.2 *Envelope Delay Distortion.* The envelope delay distortion (differential time delay between any two frequencies between 1,000 to 2,600 cps) shall not exceed 1,000 microseconds over the 6,000-nautical mile reference circuit or 160 microseconds for the multiplex equipment of one link back to back. Delays are taken to be directly additive.

3.2.2.4.1.1.3 *Total Noise.* The following standard applies to noise from all sources in any channel of a system in which the entire baseband is loaded with white noise at a level equivalent to the levels specified in CCIR Recommendation No. 294, when the number of channels is taken to be two-thirds of the actual number of channels. (CCIR Recommendation No. 294 is contained in paragraph 3.2.2.4.8.3.)
The median of hourly median values of noise from all sources on any channel of a system composed of tropospheric scatter hops in tandem over a 6,000-nautical mile reference circuit shall not exceed 25,000 picowatts (pw), psophometrically weighted (38 dba F1A weighted) at zero relative level, during time block 2.[1] The median noise power shall be divided such that 5,000 pwp is assigned to the multiplex equipment and 20,000 pwp to the transmission media. The allowable transmission media noise in a section of length L nautical miles is found by the following:

$$\text{Noise} = \frac{L}{6{,}000} \times 20{,}000 \text{ pwp}$$

The total noise over a 6,000 n.m. reference circuit shall not exceed 316,000 pwp (49 dbaO) more than a cumulative 0.1% of time block 2. For a portion of the system L nautical miles in length, the total noise shall not exceed 316,000 pwp more than a cumulative $\frac{L}{6{,}000} \times 0.1\%$ of time block 2.

In any system, the median noise level and the percent of time for which 49 dbaO is exceeded are not independent quantities. Generally, if a system will meet the median noise standard, it will meet or better the excessive noise (49 dbaO) standard. In the DCS, systems will be engineered to meet the median noise standard and then checked by the methods of the addendum to this manual to insure that the excessive noise standard is satisfied. In the event it is not, the system will be engineered to a lower median noise value such that the excessive noise standard can also be met.

3.2.2.4.1.1.4 *Harmonic Distortion.* Harmonic or in-channel distortion shall not exceed −40 dbmO for one set of multiplex equipment.

3.2.2.4.1.1.5 *Gain Change.* A measure of channel amplitude limiting is the gain change for an output level increase. To define the range below which

[1] This is time block 2 of the National Bureau of Standards time block allocations which are listed in the addendum to the standards. Time block 2 is defined as 1300–1800 local standard time November through April. In the temperate zone of the southern hemisphere, the standard applies to time block 5 (1300–1800) May through October.

there should be minimal channel limiting, and above which limiting should increase sharply to prevent overloading of common amplifiers, channel limiting requirements are as follows: (These points are to be joined by a smooth curve.)

(a) Gain reduction for an output level increase from zero dbmO to +3.5 dbmO shall not be over 0.35 db.

(b) Gain reduction for an output level increase from zero dbmO to +12 dbmO shall be at least 5 db.

3.2.2.4.1.1.6 *Net Loss Variation.* The net loss variation due to one set of multiplex audio-to-audio, back-to-back, shall not exceed ±0.2 db. Allowing for variations due to the transmission medium, the overall variation allowable for the 6,000-nautical mile reference circuit shall be ±2.0 db.

3.2.2.4.1.1.7 *Level Adjustability.* To hold system misalignment to reasonable limits, it shall be possible to adjust the level of test signals to ±0.5 db at audio points.

3.2.2.4.1.1.8 *Maximum Overall Change in Audio Frequency.* Any audio frequency entering a channel of the reference circuit shall be reconstituted at the other end with an error not exceeding ±2 cps.

3.2.2.4.1.1.9 *Stability of Multiplex Frequency Generator.* The accuracy of the initial adjustment of the master oscillators controlling the various carrier frequencies in the multiplex equipment shall be 2 parts in 10^8 of the selected frequency. The rate of frequency drift shall not exceed 2 parts in 10^7 per month. The change in frequency on changeover from the operating to the standby oscillator shall not exceed 4 parts in 10^8, due to adverse combinations of 10 percent changes in supply voltages. Means shall be provided to compare frequencies of master oscillators in the same station, and between different stations, to an accuracy of 1 part in 10^7.

3.2.2.4.1.1.10 *Single-Tone Interference.* Single frequency tones shall not exceed a level of 24 dbaO when the channel is used for active speech transmission.

3.2.2.4.1.1.11 *Data, Telegraph, and Speech Signal Levels.* In systems with many channels, with some channels loaded with voice currents, and others with data or telegraph signals, the levels of the latter shall be determined in the following manner to maintain established loading factors for the common amplifiers. When two or more data or telegraph channels are operated over the same voice channel, they shall be operated at still lower levels to produce equivalent loadings. Data or telegraph signals with FSK modulation produce constant power loading, while AM systems operated at teletypewriter speeds or higher, effectively load the voice channel about 3 db less, and hence may be set at levels 3 db higher than FSK. The maximum levels for signal tones in a voice channel shall be—

FSK	-13 dbmO
AM	-10 dbmO

For more than one subchannel per voice channel, these levels shall be reduced by ($10 \log_{10} n$) db, where n is the number of subchannels, or 3 db lower each time the number of subchannels is doubled. The mean absolute power at zero relative level for speech plus signaling currents over a telephone channel shall be -15 dbmO. It is anticipated that in a system with no voice traffic, the data or telegraph loading levels may be increased.

3.2.2.4.1.1.12 *Test Procedures.* Test procedures, where applicable, are given in chapter 5.

3.2.2.4.1.2 *Interface Parameters.* The interface parameter requirements summarized in table 3.2.2.4.1.2 differ from the transfer function parameters in that they are primarily concerned with the interconnections between transmission circuits and switching equipment or end instruments (in allocated circuits), and between different parts of the transmission system. They deal with impedance, voltage and power levels, and frequency bands, which are specified so that a building block relationship is set up to provide maximum interchangeability and flexibility. Primary interfaces occur where transmission circuits meet switching equipments or end instruments. Secondary interfaces occur within the transmission system where circuits or aggregates of circuits of the same or a different subsystem meet at audio, group, supergroup, baseband, or intermediate frequencies. All levels specified shall be within ± 0.5 db.

3.2.2.4.1.2.1 *Audio Frequency Interface.*

3.2.2.4.1.2.1.1 *Transmission Levels, Multiplex Equipment.*

(a) The input to the channel modulator shall be -16 dbr.

(b) The output from the channel demodulator shall be $+7$ dbr.

(c) The input and output levels specified apply to the multiplex equipment proper, and provide a net gain of 23 db in each one-way path. These levels shall apply to all channels of the multiplex equipment, without regard for the net loss to be provided by any particular trunk, whether terminated on a two-wire or a four-wire basis. All channels shall be maintained on the same basis, so that a -16 dbm test tone at any modulator input shall result in a $+7$ dbm output from the distant demodulator, insuring that all channels are interchangeable and may be freely patched at multiplex access points without need to change adjustments integral to the multiplex equipment.

Table 3.2.2.4.1.2. Transmission Specifications for DCS Reference Circuit (Troposcatter)—Interface Characteristics

Parameter	Requirement	
Audio Side of Multiplex Equipment (4-wire):		
Relative level, modulator input	−16 dbr	
Relative level, demodulator output	+ 7 dbr	
Impedance, balanced/channel	600 ohms	
Return loss vs. 600 ohms	26 db min	
Level adjustability	±0.5 db	
Basic Group Frequency:		
1 Basic group frequency band (12 channels)	60–108 kc	
Impedance, balanced/unbalanced	135 ohms/75 ohms	
Basic Supergroup Frequency:		
Basic supergroup frequency band (60 channels).	312–552 kc	
Impedance, unbalanced	75 ohms	
Baseband Side of Multiplex Equipment	*RF Equipment*	*Multiplex*
Relative levels (transmitting) per channel (i.e., of a test-tone)	≥ −45 dbr, input	≥ −35 dbr, output
Relative levels (receiving) per channel	≥ −15 dbr, output	≥ −25 dbr, input
Impedance, balanced/unbalanced	135/75 ohms	135/75 ohms
Return loss vs. nominal impedance	20 db, min	20 db, min
Intermediate Frequency:		
Frequency	70 mc	
Impedance, unbalanced	75 ohms	
Return loss vs. 75 ohms	20 db, min	
Signal Output level (IF repeater only)	≥0.5 volt, rms	
Signal Input level (IF repeater only)	≥0.3 volt, rms	

3.2.2.4.1.2.1.2 *Transmission Levels, Trunk.* Four-wire input and output levels of trunks, at points accessible to the restoral or switching equipment (or user equipment in the case of allocated circuits), shall be adjusted to meet levels and circuit net losses determined for each particular group of circuits by the overall transmission plan for the transmission network. Such circuit net loss adjustments shall be made independently of the multiplex equipment controls by inserting suitable attenuators or pads between the access terminals and the multiplex equipment. The 23 db net gain of the one-way channel facilitates making various interconnections to obtain special multiple or branching arrangements, to insert or bridge supervisory and monitoring equipment, etc. When two multiplex channels are permanently connected in tandem to build up a longer circuit, the level disparity shall be met by inserting 23 db loss in each side of the four-wire path.

3.2.2.4.1.2.1.3 *Impedance and Return Loss.* The impedance shall be a nominal 600 ohms, balanced to ground, with a return loss against 600 ohms of 26 db minimum over the audio bandpass with equipment lined up at correct levels.

3.2.2.4.1.2.1.4 *Level Adjustability.* Levels shall be adjustable to within ±0.5 db.

3.2.2.4.1.2.2 *Group Frequency Interface.*

(a) Frequency Band—(12 channels) 60 to 108 kc.

(b) Impedance—135 ohms, balanced to ground, or 75 ohms unbalanced, and a minimum of 20 db return loss over the group frequency range.

3.2.2.4.1.2.3 *Supergroup Frequency Interface.*

(a) Frequency Band—(60 channels) 312 to 522 kc, upper sideband of individual channels.

(b) Impedance—75 ohms, unbalanced to ground, and a minimum of 20 db return loss over the supergroup frequency range.

3.2.2.4.1.2.4 *Multiplex Baseband Interface.* This interface is of considerable importance since here the multiplex equipment meets the radio equipment of a radio relay system or the terminal carrier repeaters of a wire line system.

3.2.2.4.1.2.4.1 *Levels, Transmitting Direction.* The multiplex equipment shall deliver a multiplex signal with a per-channel relative test tone level of at least −35 dbr. The radio transmitting equipment shall operate properly on a relative level as low as −45 dbr per channel.

3.2.2.4.1.2.4.2 *Levels, Receiving Direction.* The radio receiving equipment shall deliver a multiplex signal with a per-channel relative level of at least −15 dbr. The multiplex equipment shall operate properly on a relative level as low as −25 dbr per channel.

3.2.2.4.1.2.4.3 *Impedance and Return Losses.* The nominal impedance for balanced equipment shall be 135 ohms; the nominal impedance for unbalanced equipment shall be 75 ohms. Against the nominal impedance, the return loss shall be at least 20 db. Table 3.2.2.4.1.2.6 indicates application of the balanced and unbalanced impedances according to number of channels in radio relay systems, and the frequency allocations of the baseband.

3.2.2.4.1.2.5 *Intermediate Frequency Interface.* The IF portion of radio relay equipment may provide an interface in some system designs. The following parameters shall be met:

(a) Frequency—70 mc.

(b) Impedance and Return Loss—The impedance shall be 75 ohms, unbalanced, and shall have a return loss against the nominal impedance of at least 20 db.

(c) Signal Levels In the receiving direction the IF output voltage shall be equal to or greater than 0.5 volt rms; in the transmitting direction, the required IF input voltage shall not exceed 0.3 volt, rms.

3.2.2.4.1.2.6 *Modulation Plan.* (Under consideration. See table 3.2.2.4.1.2.6.)

3.2.2.4.2 *Noise and Interference.*

3.2.2.4.2.1 The total noise from all sources appearing in any channel shall not exceed a median value of 25,000 pwp (38 dba F1A weighted) during time block 2

3.2.2.4.2.2 *Allocation.* The following allocation of allowable median noise to various parts of the DCS Reference Circuit shall be followed unless different trade-offs are dictated by particular requirements:

(a) Multiplex equipment	5,000	pwp
One Link		
Channel translation	345	pwp
Group modern equipment (2)	140	pwp
Supergroup modem equipment (3)	180	pwp
Through group filter and AGC equipment (3)	150	pwp
Total for one link	815	pwp
Total multiplex equipment for six links	4,890	pwp

(b) The 20,000 pwp median noise assigned to the transmission media shall be derived in equal parts from the two principal sources, thermal and intermodulation, thus allowing 10,000 pwp thermal and 10,000 pwp intermodulation noise.

Table 3.2.2.4.1.2.6. DCS modulation Plan

Basic (12-channel) Group: (Under consideration)

Basic (60-channel) Supergroup: Five groups translated (as upper sidebands) to occupy the basic supergroup frequency band 312 to 552 kc.

Number of channels	Freq. limts band occupied by tel. chan. (kc) (note 2)	Freq. limits baseband (kc)	Nominal impedance baseband (ohms)	Power level per channel		Continuity pilot freq. (kc) (note 1)
				Input (dbmO)≥	Output (dbmO)≥	
24	12-108	12-108	135 bal	−45	+4.5	116 (or 119)
60	12-252	12-252	135 bal	−45	+1.75	304 (or 331)
	*60-300	60-300	75 unbal	−45	−15	
120	12-552	12-552	135 bal	−45	+1.75	607 (or 304)
	*60-552	60-552	75 unbal	−45	−15	

Pilots

1. Frequency comparison and control monitoring (Under consideration)
2. Through regulating pilot (Under consideration)

Notes. 1. Frequency stability of continuity pilot shall be better than 5 parts in 10^8

2. *Bandwidth of white noise spectrum for intermodulation noise measurements

3.2.2.4.2.3 *Distribution.* A time distribution is required since troposcatter systems are subject to fading which causes the noise power to increase considerably from time to time. Excessive noise caused by unsatisfactory radio transmission shall not exceed 316,000 pwp (49 dba F1A at zero relative level), more than 0.1 percent of the time, during time block 2.

3.2.2.4.2.4 *Interference.* Unintentional interference shall not be allowed to exceed a level as follows when the channel is used for active speech transmission:

(a) Cochannel .... 24 dbaO
(b) Adjacent channel .... 21 dbaO
(c) Unidentified .... 21 dbaO

3.2.2.4.3 *Transmission Properties.* Standards relative to the determination of transmission loss are given in 3.2.2.4.4. In order to facilitate the comparison of results, the following is given so that the transmission loss determinations may be presented in a uniform manner.

3.2.2.4.3.1 *Long-Term Variations.*

3.2.2.4.3.1.1 The hourly median transmission loss not exceeded during 50%, 90%, 99%, and 99.9% of all hourly medians of the period of reference shall be determined. The period of reference shall not be less than 1 month during the winter period.[2] Data shall also be given to show the distribution of the hourly median transmission loss over the period of a year.

3.2.2.4.3.1.2 The statistical results of the transmission loss determinations shall be displayed on probability paper. The transmission loss shall be plotted along the ordinate and expressed in decibels; the percentage of time shall be plotted along the abscissa, with a scale following the Gaussian probability law, with percentages increasing from left to right.

3.2.2.4.3.2 *Short-Term Variations.* In order to compensate for the short-term (within-the-hour) variations, methods shall be provided to limit the fades to no greater than 10 db below the mean of a single Rayleigh fading signal, more than 0.01 percent of the time during any hour.

3.2.2.4.4 *Transmission Loss Calculations.*

3.2.2.4.4.1 *Radio Reference Atmosphere.* The Standard Radio Reference Atmosphere shall be the three-part model as follows:

(a) The radio refractivity, N, decreases linearly in the first kilometer above the surface; that is,

$$N = N_s + \Delta N(h - h_s),\ h_s \leq h \leq h_s + 1$$

(b) The radio refractivity, N, equals 105 at 9 km above sea level and the refractivity decreases exponentially between 1 km above the earth's surface, h_s+1, to the value of 105 at 9 km; that is,

$$N = N_1 \exp\left((-c(h - h_s - 1))\right),\ h_s + 1 \leq h \leq 9,$$

where

$$-c = \frac{1}{8 - h_s} Ln \frac{105}{N_1},$$

and

N_1 is the value of N at $h = h_s + 1$

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[2] It is recommended that the reference value of transmission loss be the median of all hourly medians within the period November-April, 1200-1800 (NBS time block 2), and the distribution of the hourly median transmission loss be determined for this period.

(c) Above 9 km the refractivity is determined by:

$N = 105 \exp((-.1424\,(h-9)))$, $h \geq 9$ km.

N is the radio refractivity.

N_s is the surface value of refractivity.

ΔN is the difference in N values at a height of 1 km above the surface and at the surface.

h is the height above sea level.

h_s is the height of the surface above sea level.

The constants for the standard radio reference atmosphere are given in table 3.2.2.4.4.1 and shall be used in the computation of the basic median transmission loss due to forward scatter in the troposphere.

3.2.2.4.4.2 *Path Geometry.* The geometrical parameters defined in figure 3.2.2.4.4.2, specifically the path distance, d, and radio horizon elevation angles α_{oo} and β_{oo}, shall be determined using factors of the accuracy specified in 3.2.2.4.7, Siting, and with the effective earth's radius, a_s, defined in table 3.2.2.4.4.1, Constants for the Standard Reference Atmospheres.

3.2.2.4.4.3 *Transmission Loss Due To Forward Scatter* The transmission loss shall be determined either by (1) computation, or (2) from path loss measurements and computation combined.

3.2.2.4.4.3.1 *Computation.* The basic equation for the computation of transmission loss shall be based on empirical data and shall contain, as a minimum, terms showing the effects of frequency, angular distance, and meteorological conditions. The computed transmission loss using the basic equation shall be an hourly median value based on the Standard Reference Atmospheres (3.2.2.4.4.1) and on geometrical parameters to the accuracy specified in 3.2.2.4.7. The data shall be presented to show the hourly median transmission loss not exceeded for 50%, 90%, 99%, and 99.9% of all hours during the period of reference.

Table 3.2.2.4.4.1. Constants for the Standard Reference Atmosphere

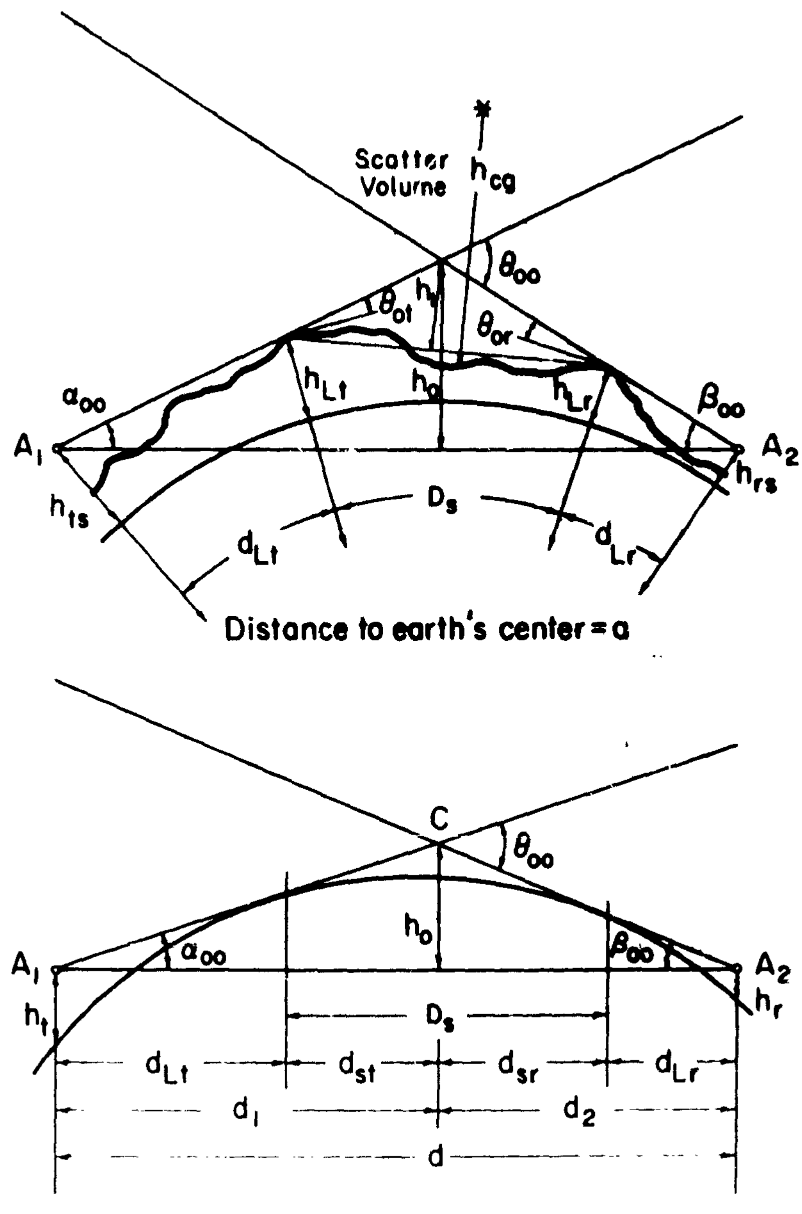
N_s	h_s feet	a' miles	$-\Delta N$	k	a_s miles	c per KM
0	0	3960.0000	0	1.00000	3960.00	0
200	10,000	3961.8939	22.3318	1.16599	4619.53	0.106211
250	5,000	3960.9470	?9.5124	1.23165	4878.50	0.114559
301	1,000	3960.1804	39.2320	1.33327	5280.00	0.118710
313	900	3960.1324	41.9388	1.36479	5403.88	0.121796
350	0	3960.0000	41.5530	1.48905	5896.66	0.130579
400	0	3960.0000	68.1295	1.76684	6996.67	0.143848
450	0	3960.0000	90.0406	2.34506	9286.44	0.154004

Notes. a_s is the effective earth's radius and is eq[illegible] to $a'k$

$a' = a + h_s$ where h_s is the height of the earth's surface above sea level

$a = 3{,}960$ miles

$$c = \frac{1}{8 - h_s} \ln \frac{N_1}{105}$$



Distances are measured in statute miles along a great circle arc

$$\theta_{oo} = \frac{D_s}{a} + \theta_{ot} + \theta_{or}$$

Figure 3.2.2 4.4.2. Geometry for a Linear Gradient Atmosphere.

3.2.2.4.4.3.2 *Measurement.* Measurement of the transmission loss for a particular path shall be considered of value only if the following conditions are met:

(a) The measurement period is of a duration sufficient to significantly reduce the prediction uncertainty of the median value of transmission loss to 3 db or less, but in any case, is not less than 20 days.

(b) The measurement apparatus is placed at the actual terminal location, or at a terminal location so the station elevations, antenna heights, and obstacle points are equivalent to the actual path.

(c) The frequency used for the measurement is within ±25 percent of the operating frequency of the proposed system.

The data collected shall be presented to show the transmission loss not exceeded for 0.1%, 1%, 10%, 50%, 90%, 99%, and 99.9% of all hours during the period of measurement.

The measurement data shall be used only to decrease the prediction uncertainty of the computed transmission loss, and shall not be used in lieu of the computed transmission loss.

3.2.2.4.5 *Frequency Assignment.*

3.2.2.4.5.1 *Unit of Separation.* The unit of frequency separation shall be 0.8 mcs, and the spacing between frequency allocations used in a given system shall be an integral multiple of 0.8 mcs.

3.2.2.4.5.2 *Transmit-Receive Frequency Separation.*

(a) The minimum separation between a transmit and receive carrier frequency of the same polarization on the same antenna shall be 120 mcs.

(b) Where two frequency channels are handled on separate antennas, or at different polarizations, the frequency separation in (a) above may be reduced by an amount corresponding to the increased loss between the two frequencies, but shall not be less than (c) below.

(c) The minimum separation between a transmit and receive carrier frequency at a single station shall be 50 mcs, but in any case, an integral multiple of 0.8 mcs.

(d) To avoid interference within a single station, separation of the transmit-receive frequencies shall not be near the first IF frequency of the receiver.

3.2.2.4.5.3 *Transmit (Receive) Frequency Separations.* The minimum separation of transmit (receive) carrier frequencies shall be seven units (5.6 mcs) for systems with 36 channels or less. (Table 3.2.2.4.5.3 shows the recommended separation for a larger number of channels.)

3.2.2.4.5.4 *Frequency Plan.* The frequency channels shall be assigned on a hop-by-hop basis such that the median value of an unwanted signal in the receiver, due to using the same or adjacent frequency channels in two relay sections, shall be at least 10 db below the inherent noise level of the receiver. (A recommended frequency plan is shown in figure 3.2.2.4.5.4.)

3.2.2.4.6 *Equipment Performance.*

3.2.2.4.6.1 *Antennas.* The antennas used at each station shall be the broad band, high gain parabolic-reflector type, capable of operating satisfactorily on any of the possible assigned frequencies in the band of operation specified.

3.2.2.4.6.1.1 *Characteristic Impedance.* The characteristic impedance shall be a nominal 50 ohms.

3.2.2.4.6.1.2 *Voltage Standing Wave Ratio (VSWR).* The VSWR shall not exceed 1.2 to 1.

3.2.2.4.6.1.3 *Diversity.* In order to maintain continuity in transmission, two distinct transmission systems shall be provided in each direction in each hop, the combination of which shall provide diversity.

Table 3.2.2.4.5.3. Transmit (Receive) Frequency Separations

Maximum number of channels	Maximum IF bandwidth	Frequency separation
36	3 mcs	5.6 mcs
60	6 mcs	11.2 mcs
120	10 mcs	16.8 mcs

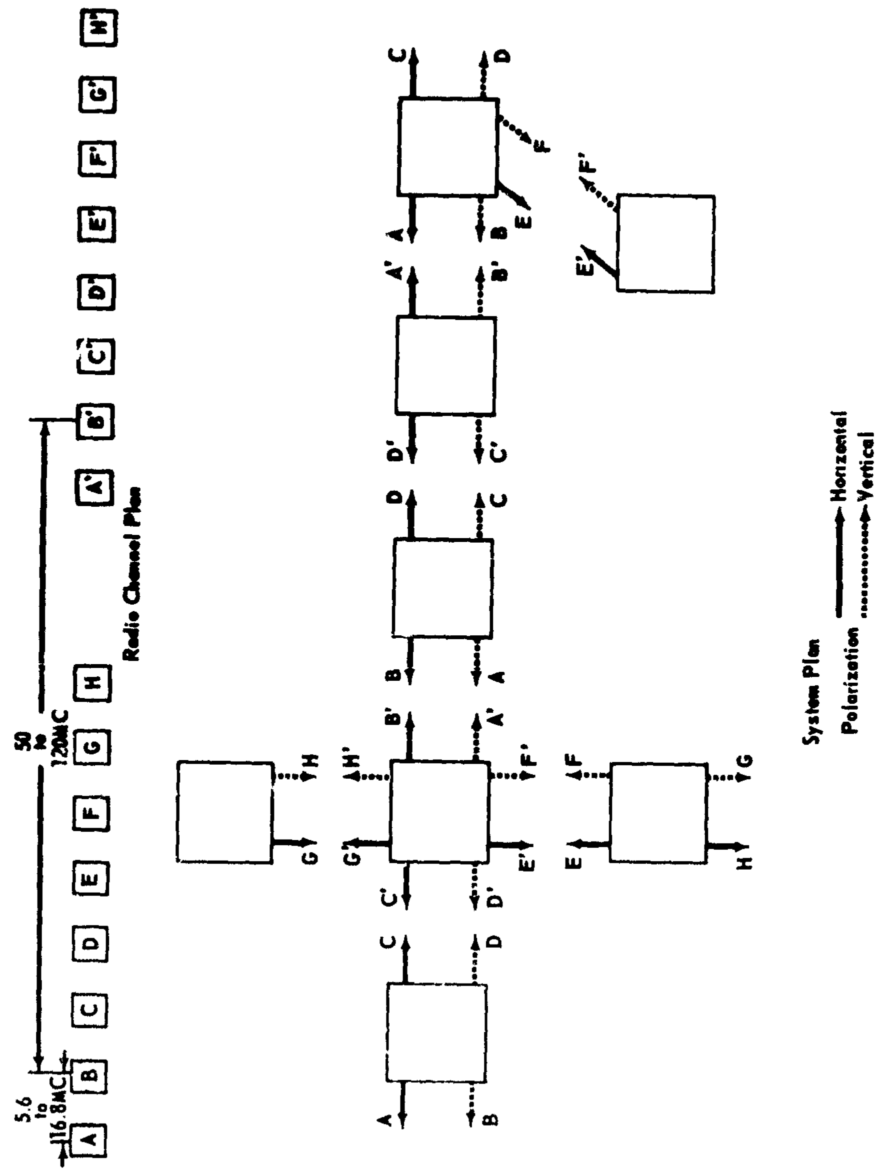


Figure 3.2.2.4.5.4. Frequency Plan.

3.2.2.4.6.1.3.1 *Spacing.* In order that fading of the received signals be substantially uncorrelated, antennas placed in space diversity should be spaced at 100 wavelengths apart or greater, but in no case be less than 70 wavelengths, in the direction normal to the great circle route to the adjacent station.

3.2.2.4.6.2 *Transmission Line.* The transmission line used shall be capable of transmitting the RF power required with the characteristics listed below. The use of coaxial connectors shall be held to a minimum. The length of any transmission line shall be held to a minimum commensurate with good engineering practice and shall not exceed 200 feet in any case.

3.2.2.4.6.2.1 *Characteristic Impedance.* The characteristic impedance shall be a nominal 50 ohms.

3.2.2.4.6.2.2 *Voltage Standing Wave Ratio (VSWR).* The VSWR shall be less than 1.05 to 1 when terminated in the characteristic impedance of the line.

3.2.2.4.6.3 *Receiving Equipment.* The several receivers provided for diversity reception at each station shall have similar characteristics, and as an optional feature, each shall have provisions for a parametric amplifier to achieve a noise figure of 2 db or less for frequencies below 3,000 mc and 3 db or less above 3,000 mc, and threshold extension to extend the threshold 7 db or more below the design value.

3.2.2.4.6.3.1 *RF Input Impedance.* The nominal RF input impedance shall be 50 ohms.

3.2.2.4.6.3.2 *Frequency Stability.* The center frequency of the receiver shall be controlled to ±0.01 percent or better for all operating conditions.

3.2.2.4.6.3.3 *Image and Out-of-Band Frequency Rejection.* Image and out-of-band frequencies shall be rejected by at least 60 db.

3.2.2.4.6.3.4 *Intermediate Frequency Characteristics.* The nominal center value of the intermediate frequency shall be 70 mc. The nominal output impedance shall be 75 ohms, unbalanced. In the receiving direction, the IF output voltage shall be equal to or greater than 0.5 volt, rms; in the transmitting direction, the required IF input voltage shall not exceed 0.3 volt, rms. The transmission amplitude characteristic shall be uniform within ±1.5 db over the intermediate frequency band.

3.2.2.4.6.4 *Transmitting Equipment.*

3.2.2.4.6.4.1 *Carrier Frequency Stability.* The carrier frequency shall be controlled to within ±0.01 percent.

3.2.2.4.6.4.2 *Exciter Output Impedance.* The nominal exciter output impedance shall be 50 ohms.

3.2.2.4.6.4.3 *Power Amplifier Input-Output Impedances.* The input and output impedances of the power amplifier shall be nominally 50 ohms

3.2.2.4.6.4.4 *Spurious Emission Supression.* Spurious emissions occuring outside the assigned band shall be suppressed 80 db or more below the carrier output.

3.2.2.4.6.4.5 *Preemphasis Characteristic.* Where preemphasis[3] is used, the preemphasis characteristic shall be such that the effective (rms) deviation due to the multichannel signal is the same with and without preemphasis.

[3] It is recommended that the preemphasis characteristics be that obtained by the network given in CCIR Recommendation No. 275

3.2.2.4.6.5 *Multiplexing Equipment.* Characteristics of the multiplexing equipment are specified in 3.2.2.4.1.1, Transfer Function Parameters, 3.2.2.4.1.2, Interface Parameters and 3.2.3.3, Performance Standards for Frequency Division Channeling Equipment.

3.2.2.4.6.6 *Test Procedures.* Test procedures, where applicable, are given in chapter 5.

3.2.2.4.7 *Siting.* The determination of path parameters shall be in three parts: (1) the preliminary determination, (2) the site survey, and (3) the final determination.

3.2.2.4.7.1 *Preliminary.* When a preliminary study is made, prior to actual site survey, such that several alternate sites are selected, maps shall be used with a scale of at least 1 in 250,000 with contours at not more than 60-meter intervals. Distance shall be determined to the nearest mile.

3.2.2.4.7.2 *Site Survey.* The selected site(s) shall be surveyed, such that a terrain profile may be constructed showing the distances and elevations along the path azimuth, with an accuracy not less than the following:

(a) Coordinates to third order accuracy.

(b) Elevations to the nearest 5 meters.

3.2.2.4.7.3 *Final Determination.* The final path parameters (path profile) shall be determined with an accuracy not less than the following:

(a) All distances to 0.1 mile.

(b) All azimuths to 10 seconds.

(c) Maps utilized shall have a scale of 1 in 25,000 with contours at 5-meter intervals. In areas where maps to this scale are not available, a scale of up to 1 in 100,000 with contours at not more than 30-meter intervals may be used.

3.2.2.4.7.4 *Hazards.* The following conditions shall apply regarding hazards to personnel and equipment:

(a) The area in the vicinity of the antenna(s) shall be restricted to prevent inadvertent entry so that personnel not be exposed to either continuous or intermittent power levels in excess of 0.01 watts per square centimeter, average power.

(b) The area in the vicinity of the high power equipment shall be restricted to prevent inadvertent entry so that personnel not be exposed to X-radiation exceeding 2.5 milliroentgens per hour or 100 milliroentgens during a 40-hour week.

(c) Fuel storage areas shall not be exposed to RF power in excess of 5.0 watts per square centimeter, peak power.

(d) Power levels constituting hazards to explosives have not been firmly established.

(e) Power levels constituting hazards to equipment have not been firmly established.

3.2.2.4.8 *Systems Performance.* For analysis purposes, it is convenient to consider systems performance in terms of (1) Single Hop Performance, and (2) Tandem Hop Performance.

3.2.2.4.8.1 *Single Hop Performance.*

3.2.2.4.8.1.1 *Noise in a Real Circuit.* The psophometrically weighted noise power excluding multiplex equipment noise, at a point of zero relative level in the audio channels of a real troposcatter hop of length L nautical miles, where L is less than 1,000 nautical miles and whose composition does not differ appreciably from the DCS Reference Circuit, shall not—

(a) Exceed [4] 3.33L pwp median during time block 2.

(b) Exceed 316,000 pwp more than a cumulative $\frac{L}{1{,}000}\times 0.02$ percent of time block 2.

3.2.2.4.8.1.2 *Performance Tests.* Performance tests shall be made on each hop to determine the quality of transmission.[5] These tests shall be in two parts: (1) local tests, and (2) transmission system tests.

3.2.2.4.8.1.2.1 *Local Tests.* The local tests, from multiplex input to multiplex output including the radio transmitter and receiver, shall include but not be limited to those tests required to establish the characteristics specified in 3.2.2.4.1.1 Transfer Function Parameters. (Procedures are given in chapter 5.)

3.2.2.4.8.1.2.2 *Transmission System Tests.* The transmission system tests, including the propogation medium shall include as a minimum the measurement of stability of the net gain or loss in the baseband and total noise including intermodulation noise. (See 3.2.2.4.8.3.)

3.2.2.4.8.1.2.3. *Duration of Measurement.*

3.2.2.4.8.1.2.3.1. *Continuous Uniform Spectrum.* Total noise measured in each direction in each hop with a continuous uniform spectrum signal shall be of a duration necessary to establish a correlation between the total channel noise and the received signal power, but in any case shall not be less than 72 hours valid data.

3.2.2.4.8.1.2.3.2 *Received Signal Level.* The received signal power in each direction in each hop shall be recorded continuously for a period not less than 30 days (preferably 6 months). This data shall be presented to show the signal power exceeded 0.1%, 1%, 10%, 50%, 90%, 99%, and 99.9% of all hours during the period of measurement. The correlation between the received signal power and total channel noise shall be shown.

3.2.2.4.8.1.2.3.3 *Noise in Actual Traffic.* The total noise measured in actual traffic in each hop in each direction after the system is in operation shall be recorded continuously for a period not less than 30 days (preferably 6 months).

3.2.2.4.8.2 *Tandem Hop Performance.*

3.2.2.4.8.2.1 *Noise in a Real Circuit.* The psophometrically weighted noise power, excluding multiplex equipment noise, at a point of zero relative level in the audio channels of a real troposcatter system of length L nautical miles, where L is between 1,000 and 6,000 nautical miles, and whose composition does not differ appreciably from the DCS Reference Circuit shall not—

(a) Exceed [6] 3.33 L pwp median during time block 2.

(b) Exceed 316,000 pwp more than a cumulative $\frac{L}{6{,}000}\times 0.1$ percent of time block 2.

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[4] It is not expected that all hops will meet this noise limit, some hops will be better and some worse; however, the cumulative noise power from all hops in tandem within the 1,000-nautical mile reference link shall meet the performance criteria specified.

[5] It is assumed that each piece of equipment has been properly installed and adjusted, and that transmission levels have been properly set.

[6] It is assumed that at the demodulation points of a real circuit, the audio channels, groups, and supergroups are interconnected at random. In particular, it is assumed that the noise coming from the different sections is power additive

3.2.2.4.8.2.2 *Performance Tests.* Tandem hop performance tests over the entire system shall include as a minimum the measurement of stability of the net gain or loss in the baseband and total noise including intermodulation noise.

3.2.2.4.8.2.2.1 *Duration of Noise Measurement.* The total noise in each direction in the entire system shall be recorded for a period to provide 72 hours of valid data as soon as practicable after initial installation.

3.2.2.4.8.3 *Total Noise Measurement.* Total noise, including crosstalk noise, should be measured with a continuous uniform spectrum signal or during actual traffic. Measurement with a continuous uniform spectrum signal is made while the system is not carrying actual traffic and with a white noise signal representing system loading during busy hours; measurement during actual traffic is made in bands just outside the total multiplex band, in actual traffic conditions.

3.2.2.4.8.3.1 *Measurement With Continuous Uniform Spectrum Signal.* It is desirable to be able to measure the performance of radio relay systems which are for use with FDM under conditions closely approaching those of actual operation, without necessarily having FDM equipment installed and connected. For systems with 12 or more channels, it has been established that a white noise signal (a signal with a continuous uniform spectrum) has statistical properties similar to those of a multichannel multiplex signal. This type of test uses a white noise generator producing a spectrum of width corresponding to the multiplex signal it replaces, but with specified gaps produced by stop filters, at the lower and upper edges of the baseband (just within or just outside) and at the center of the baseband. The noise measurements are made in the stop bands, through suitable receiving filters. Specifications are given below for those parameters. They correspond to CCIR Recommendation 294 (Warsaw, 1956—Los Angeles, 1959).

(a) White noise signal spectrum—Table 3.2.2.4.8.3.1 gives the bandwidth for systems with 24 to 600 channels, for the allocations starting at 12 kc at the lower edge.

(b) White noise signal power levels—The power level of the white noise signal is computed according to the following formulas, relative to 1 mw at a point of zero transmission level, where n is the total number of channels in the circuit:

(1) For systems with from 60 to 240 telephone channels:
Power level $= (-1+4 \log_{10}n)$ dbmO
(Provisionally applies down to minimum of 12 channels.)

(2) For system with 240 to 600 channels (or more):
Power level $= (-15+10 \log_{10}n)$ dbmO

(c) Within the specified band, the rms noise voltage levels measured with a narrow bandwidth of about 2 kc should not vary more than 1 db. Outside of this band, the power should drop sharply and be more than 25 db down at all frequencies greater than 10% above and 20% below the band.

(d) Stop and band filters—To clear the measurement channels of white noise stop band filters are required at the output of the white noise generator. The center frequencies of these filters should be the same as for the measuring channels shown in table 3.2.2.4.8.3.1. Three filters should be used in a given case, including the center channel and either the outside band (OB) or inside band (IB) channels. The attenuation of noise in each stop band at the generator output should exceed 80 db over a band at least 3-kc wide, and should not exceed 3 db at frequencies of $\pm$ $(0.02f+4)$ kc, where f is the center frequency in kc. The shape of the filter characteristics should be such that, when all three band stop filters are simultaneously brought into the circuit, the errors in measurement as compared with a measurement carried out with a perfectly uniform source and an indefinitely narrow stop band should not exceed 1 db. Error here means the loss due to insertion of filters, to changes in spectral distribution of thermal and intermodulation noise produced by the insertion, and to other causes.

(e) Measurement filters—Intermodulation noise measurements should be performed in the same bands provided in the particular case, with stop band filters as described in the preceding paragraph. The use of these channels is preferred for special tests, calibration, etc. The effective bandwidth of the measuring filters in the receiving equipment should be designed to be narrow enough to provide satisfactory measurements, taking into account the possibility of stop band filter attenuation as low as 3 db at the frequencies $\pm (0.2f+4)$ kc with respect to the center frequencies, as allowed in the stop band filter requirements.

(f) Additional or alternative measuring channels—These may be used as required by circumstances.

(g) Noise power ratio (NPR) or slot noise power ratio is the ratio of the noise power appearing in a measurement channel with the corresponding stop band filter first out of the circuit and then in the circuit. The change in level is independent of the precise width of the measurement channel.

3.2.2.4.8.3.2 *Measurement of Noise in Actual Traffic.* Once a radio relay system is placed in service carrying FDM channels, it may be difficult or impossible to withdraw it from traffic at will for measurement of noise by the use of white noise signals. It is therefore desirable to specify measurement channels outside but reasonably close to the total bandwidth of the multiplex signal, in order to measure the intermodulation products due to the nonlinearity of the system. It is desirable to measure noise in a channel just above the multiplex band, since this is generally more sensitive to changes of thermal and intermodulation noise in the RF and IF parts of the equipment. On the other hand, measurements in a channel below the multiplex band are more sensitive to changes in the modulators and demodulators. It is usually necessary to use stop band filters at the input of a system to minimize noise on the incoming circuit in the bands occupied by the measuring channels. The following requirements are derived from CCIR Recommendation 293 (Los Angeles, 1959).

(a) Stop band filters The attenuation of the stop band filters at the input of the system should exceed 50 db over a minimum frequency band $\pm(0.005f+2)$ kc, where f is the center frequency of the measuring channel in kc The additional attenuation caused by the insertion of the stop filters at the lower edge and at the upper edge of the total multiplex band should not exceed 0.3 db referred to the additional attenuation caused in the center of the multiplex signal band. The center frequencies of the noise measuring channels are given in table 3.2.2.4.8.3.1. When the center frequency is 10 kc, the minimum frequency band is to be ±1 kc instead of the band calculated according to the formula given.

(b) **Measurement filters**—The characteristics of the measurement filters, the center frequencies of which are given in table 3.2.2.4.8.3.1, should be designed to be sufficiently narrow to give satisfactory measurements, taking into amount the characteristics of the band stop filters.

(c) **Continuity pilots**—Frequencies given in table 3.2.2.4.8.3.1 for continuity pilots agree with the central frequencies of the noise measuring channels above the multiplex band. It may be useful to combine the evaluation of the power of the continuity pilot with the measurement of the noise around it.

(d) **Filter designs**—It is desirable that design of band stop and measuring filters should enable them to be used both for maintenance measurements and for measurements of white noise.

(e) **Disconnection of certain channels**—In certain telephone channels, and in combinations of them, harmonic distortion may be produced. This may make it necessary to leave these channels disconnected. (For example, if the second or third harmonics coincide with the central frequencies of the noise measuring channels.)

Table 3.2.2.4.8.3.1. Parameters for Radio Relay Systems

Number of channels	Freq. limits band occupied by tel. chan. (kc) (note 3)	Freq. limits baseband (kc)	Continuity pilot freq. (kc) (note 1)	Noise measuring channels center frequencies in kc							
				Actual traffic		White noise (note 2)					
				Below	Above	Lower		Center	Upper		
						OB	IB		IB	OB	
24	12-108	12-108	116 (or 119)	10	116 (or 119)	----	----	------	----	----	
60	12-252	12-252	304 (or 331)	10	304	50	70	------	270	331	
	*60-300	60-300		50	331						
120	12-252	12-252	607 (or 304)	10	607	50	70	270	534	607	
	*60-552	60-552		50	607						
300	*60-1300	60-1364	1499	50	1499	50	70	534	1248	[illegible]	
	64-1296										
600	*60-2540	60-2792	3200	50	3200	50	70	1248	2438	3200	
	*64-2660										

Notes 1 Frequency stability of continuity pilot should be better than 5 parts in 10^{8}.
2 Lower and upper measuring channels may be either outside (OB) or inside (IB) the band of white noise signal.
3 *Bandwidth of white noise spectrum for intermodulation noise measurements.

3.2.2.5 *Microwave Line-of-Sight Systems.*

3.2.2.5.1 *DCS Reference Circuit (Microwave Line-of-Sight).* The composition of the DCS Microwave Line-of-Sight Reference Circuit coincides with that of the DCS Wideband Reference Circuit described in paragraph 3.2.1. The DCS Microwave Line-of-Sight Reference Circuit is further described in the following paragraphs in terms of its transfer functions and interface parameters. Actual microwave line-of-sight circuits which are a part of the DCS shall be designed to have these transfer functions and interface parameters.

3.2.2.5.1.1 *Transfer Function Parameters.* The transfer function parameters define the properties of the DCS Microwave Line-of-Sight Reference Circuit in terms of circuits utilizing 4-kc channel allocations, involving the various distortions, noise, stability, adjustment, and signal level loading. As indicated in table 3.2.2.5.1.1, the parameters may be defined within three aspects: overall reference circuit, transmission medium (including repeaters), and multiplex equipment (for one nominal 1,000 nm link).

Table 3.2.2.5.1.1. Transmission Specifications for DCS Reference Circuit Transfer Function

Parameter	Overall reference circuit 6,000 nm (6 links)	Normally assignable to— Transmission medium, including repeaters (6 links)	Normally assignable to— Multiplex equipment (1 link only)	
Insertion loss-frequency, ref to 1,000 cps:				
600–1,400 cps	+4.0 −4.0db	....	+0.7	−0.7db
400–3,000 cps	+9.0 −4.0db	....	+1.5	−0.7db
300–3,400 cps	+18.0 −4.0db	....	+3.0	−0.7db
Envelope Delay Distortion, 1,000–2,600 cps max.	1,000 μsec	....	160 μsec	
Median noise level, from all sources, worst hour, worst month:			*Term Only*	*Term & Intermed*
Psophometrically weighted at OTLP, pwp	25,000	20,000	475	815
Equiv. white noise, F1A line wtg, dbaO	38.0	37.0	20.8	23.1
Harmonic distortion	....	....	−40 dbmO	
Gain change for output level increase from 0 dbmO, to— +3.5 dbmO	....	....	0.35 db max	
Gain change for output level increase from 0 dbmO, to— +12.0 dbmO	....	....	6.0 db min	
Net loss variation, max at 1,000 cps audio, or at any baseband frequency	±2.0 db	±0.5 db	±0.2 db	
Level adjustability	....	±0.5 db	±0.5 db	
Max. overall change in any audio freq.	±2 cps	....	±2 cps	
Stability of multiplex frequency generator: Initial setting to—	....	....	2 parts in 10^8	
Stability of multiplex frequency generator: Drift per month	....	....	2 parts in 10^7	
Single tone interference	24 dbaO	....	....	
Max. data/telegraph levels, single channel high speed	....	....	(FSK) −13 dbmO	
	....	....	(AM) −10 dbmO	
Speech level	....	....	−15 dbmO	

Notes 1 The noise power shall be divided such that 5,000 pwp is assigned to the multiplex equipment and 20,000 pwp to the transmission media.

2 The allowable transmission media noise in a section of length L nautical miles (L less than the 6,000 nautical mile reference circuit) is found by—

$$\text{Noise} = \frac{L}{6000} \times 20{,}000 \text{ pwp}$$

3 The total noise shall not exceed 316,000 pwp (49 dbaO) 1 minute mean value more than a cumulative 0.1 percent of the worst month.

3.2.2.5.1.1.1 *Insertion Loss vs. Frequency.* The response characteristics are stated in terms of insertion loss referred to the 1,000 cps loss. Thus, a positive figure denotes lower response, and a negative figure indicates a higher response relative to 1,000 cps.

Single Link Channel Frequency Response

The frequency response referred to 1,000 cps for the multiplex equipment (1 link only) shall be as follows:

600–2,400 cps	+0.7	−0.7 db
400–3,000 cps	+1.5	−0.7 db
300–3,400 cps	+3.0	−0.7 db

Overall Circuit Frequency Response

The frequency response referred to 1,000 cps for the overall 6,000-nautical mile circuit shall be as follows:

600–2,400 cps	+4.0	−4.0 db
400–3,000 cps	+9.0	−4.0 db
300–3,400 cps	+18.0	−4.0 db

3.2.2.5.1.1.2 *Envelope Delay Distortion.* The envelope delay distortion (differential time delay between any two frequencies between 1,000 and 2,600 cps) shall not exceed 1,000 microseconds over the 6,000-nautical mile reference circuit, or 160 microseconds for the multiplex equipment of one link back-to-back. Delays are taken to be directly additive.

3.2.2.5.1.1.3 *Total Noise.* The following standard applies to noise from all sources in any channel of a system in which two-thirds of the channels are loaded (loading simulated with white noise or actual loading with equivalent traffic.) Noise is measured in an idle channel at, or referred to, a OTLP, and is a measure of the relationship of circuit noise to a constant value signal, the level of which is controlled by AGC action; i.e., a standard test tone clamped to 0 dbmO in a receive channel.

The total noise from all sources on any channel of a system composed of line-of-sight hops in tandem over a 6,000-nautical mile reference circuit shall not exceed 25,000 picowatts (pw), psophometrically weighted (38 dba FIA weighted) at zero relative level, during the worst hour of the month of poorest transmission. The noise power shall be divided such that 5,000 pwp is assigned to the multiplex equipment and 20,000 pwp to the transmission media. The allowable transmission media noise in a section of length L nautical miles is found by the following:

$$\text{Noise} = \frac{L}{6{,}000} \cdot 20{,}000 \text{ pwp}$$

The total noise over a 6,000 nm reference circuit shall not exceed 316,000 pwp (49 dbaO) 1-minute mean value more than a cumulative 0.01 percent of the worst month. For a portion of the system L nautical miles in length, the total noise shall not exceed 316,000 pwp more than a cumulative $\frac{L}{6{,}000} \cdot 0.01\%$ of the worst month.

3.2.2.5.1.1.4 *Harmonic Distortion.* Harmonic or in-channel distortion shall not exceed −40 dbmO for one set of multiplex equipment.

3.2.2.5.1.1.5 *Gain Change.* A measure of channel amplitude limiting is the gain change for an output level increase. To define the range below which there should be minimal channel limiting, and above which limiting should increase sharply to prevent overloading of common amplifiers, channel limiting requirements are as follows:

(a) Gain change for an output level increase from zero dbmO to +3.5 dbmO shall not be over 0.35 db.

(b) Gain change for an output level increase from zero dbmO to +12 dbmO shall be at least 5 db.

3.2.2.5.1.1.6 *Net Loss Variation.* The net loss variation due to one set of multiplex audio-to-audio, back-to-back, shall not exceed ±0.2 db. Allowing for variations due to the transmission medium, the overall variation allowable for the 6,000-nautical mile reference circuit shall be ±2.0 db.

3.2.2.5.1.1.7 *Level Adjustability.* To hold system misalignment to reasonable limits, it shall be possible to adjust the level of test signals to ±0.5 db, particularly at interfaces in the system.

3.2.2.5.1.1.8 *Maximum Overall Change in Audio Frequency.* Any audio frequency entering a channel of the reference circuit shall be reconstituted at the other end with an error not exceeding ± 2 cps.

3.2.2.5.1.1.9 *Stability of Multiplex Frequency Generator.* The accuracy of the initial adjustment of the master oscillators controlling the various carrier frequencies in the multiplex equipment shall be 2 parts in 10^8 of the selected frequency. The rate of frequency drift shall not exceed 2 parts in 10^7 per month. The change in frequency on changeover from the operating to the standby oscillator shall not exceed 4 parts in 10^8, due to adverse combinations of 10 percent changes in supply voltages. Means shall be provided to compare frequencies of master oscillators in the same station, and between different stations, to an accuracy of 1 part in 10^7.

3.2.2.5.1.1.10 *Single Tone Interference.* Single frequency tones shall not exceed a level of 24 dbaO when the channel is used for active speech transmission.

3.2.2.5.1.1.11 *Data, Telegraph, and Speech Signal Levels.* In systems with many channels, with some channels loaded with voice currents, and others with data or telegraph signals, the levels of the latter shall be determined in the following manner to maintain established loading factors for the common amplifiers. When two or more data or telegraph channels are operated over the same voice channel, they shall be operated at still lower levels to produce equivalent loadings. Data or telegraph signals with FSK modulation produce constant power loading, while AM systems operated at teletypewriter speeds or higher, effectively load the voice channel about 3 db less, and hence may be set at levels 3 db higher than FSK. The maximum levels for signal tones in a voice channel shall be—

FSK	−13 dbmO
AM	−10 dbmO

For more than one subchannel per voice channel, these levels shall be reduced by ($10 \log_{10} n$) db, where n is the number of subchannels, or 3 db lower each time the number of subchannels is doubled. The mean absolute power at zero relative level for speech plus signaling currents over a telephone channel shall be -15 dbm0. It is anticipated that in a system with no voice traffic, the data or telegraph loading levels may be increased.

3.2.2.5.1.1.12 *Test Procedures.* Test procedures, where applicable, are given in chapter 5.

3.2.2.5.1.2 *Interface Parameters.* The interface parameter requirements summarized in table 3.2.2.5.1.2 differ from the transfer function parameters in that they are primarily concerned with the interconnections between transmission circuits and switching equipment or end instruments (in allocated circuits), and between different parts of the transmission system. They deal with impedance, voltage and power levels, and frequency bands, which are specified so that a building block relationship is set up to provide maximum interchangeability and flexibility. Primary interfaces occur where transmission circuits meet switching equipments or end instruments. Secondary interfaces occur within the transmission system where circuits or aggregates of circuits of the same or a different subsystem meet at audio, group, supergroup, baseband, or intermediate frequencies. All levels specified shall be within ± 0.5 db.

Table 3.2.2.5.1.2. Transmission Specifications for DCS Reference Circuit Interface Characteristics

Parameter	Requirement	
Audio Side of Multiplex Equipment (4-wire):		
Relative level, modulator input	-16 dbr	
Relative level, demodulator output	$+7$ dbr	
Impedance, balanced/channel	600 ohms	
Return loss vs. 600 ohms	26 db min.	
Level adjustability	± 0.5 db	
Basic Group Frequency:		
1 Basic group frequency band (12 channels)	60–108 kc	
Impedance, balanced/unbalanced	135 ohms/75 ohms	
Basic Supergroup Frequency:		
Basic supergroup freq. band (60 channels)	312–552 kc	
Impedance, unbalanced	75 ohms	
Baseband Side of Multiplex Equipment:	*RF equipment*	*Multiplex*
Relative levels (transmitting) per channel*	≥ -45 dbr, input	≥ -35 dbr, output
Relative levels (receiving) per channel	≥ -15 dbr, output	≥ -25 dbr, input
Impedance, balanced/unbalanced	135/75 ohms	135/75 ohms
Return loss vs. nominal impedance	20 db, min.	20 db, min.
Intermediate Frequency		
Frequency	70 mc	
Impedance, unbalanced	75 ohms	
Return loss vs. 75 ohms	20 db, min	
Signal output level (IF repeater only)	≥ 0.5 volt, rms	
Signal input level (IF repeater only)	≥ 0.3 volt, rms	

*(i.e., of a test tone.)

3.2.2.5.1.2.1 *Audio Frequency Interface.*

3.2.2.5.1.2.1.1. *Transmission Levels, Multiplex Equipment.*

(a) The input to the channel modulator shall be -16 dbr.

(b) The output from the channel demodulator shall be +7 dbr.

(c) The input and output levels specified apply to the multiplex equipment proper, and provide a net gain of 23 db in each one-way path. These levels shall apply to all channels of the multiplex equipment, without regard for the net loss to be provided by any particular trunk, whether terminated on a two-wire or a four-wire basis. All channels shall be maintained on the same basis, so that a −16 dbm test tone at any modulator input shall result in a +7 dbm output from the distant demodulator, insuring that all channels are interchangeable and may be freely patched at multiplex access points without need to change adjustments integral to the multiplex equipment.

3.2.2.5.1.2.1.2 *Transmission Levels, Trunk.* Four-wire input and output levels of trunks, at points accessible to the restoral or switching equipment (or user equipment in the case of allocated circuits), shall be adjusted to meet levels and circuit net losses determined for each particular group of circuits by the overall transmission plan for the transmission network. Such circuit net loss adjustments shall be made independently of the multiplex equipment controls by inserting suitable attenuators or pads between the access terminals and the multiplex equipment. The 23 db net gain of the one-way channel facilitates making various interconnections to obtain special multiple or branching arrangements, to insert or bridge supervisory and monitoring equipment, etc. When two multiplex channels are permanently connected in tandem to build up a longer circuit, the level disparity shall be met by inserting 23 db loss in each side of the four-wire paths.

3.2.2.5.1.2.1.3 *Impedance and Return Loss.* The impedance shall be a nominal 600 ohms, balanced to ground, with a return loss against 600 ohms of 26 db minimum over the audio bandpass with equipment lined up at correct levels.

3.2.2.5.1.2.1.4 *Level Adjustability.* Levels shall be adjustable to within ±0.5 db.

3.2.2.5.1.2.2 *Group Frequency Interface.*

(a) Frequency Band—(12 channels) 60 to 108 kc, lower sidebands.

(b) Impedance—135 ohms, balanced to ground or 75 ohms unbalanced, and a minimum of 20 db return loss over the group frequency range.

3.2.2.5.1.2.3 *Supergroup Frequency Interface.*

(a) Frequency Band—(60 channels) 312 to 552 kc, upper sidebands of individual channels.

(b) Impedance 75 ohms, unbalanced to ground, and a minimum of 20 db return loss over the supergroup frequency range.

3.2.2.5.1.2.4 *Multiplex Baseband Interface.* This interface is of considerable importance since here the multiplex equipment meets the radio equipment of a radio relay system or the terminal carrier repeaters of a wire line system.

3.2.2.5.1.2.4.1 *Levels, Transmitting Direction.* The multiplex equipment shall deliver a multiplex signal with a per-channel relative test tone level of at least −35 dbr. The radio or wire line transmitting equipment shall operate properly on a relative level as low as −45 dbr per channel.

3.2.2.5.1.2.4.2 *Levels, Receiving Direction.* The radio or wire line receiving equipment shall deliver a multiplex signal with a per-channel relative level of at least −15 dbr. The multiplex equipment shall operate properly on a relative level as low as −25 dbr per channel

3.2.2.5.1.2.4.3 *Impedance and Return Losses.* The nominal impedance for balanced equipment shall be 135 ohms; the nominal impedance for unbalanced equipment shall be 75 ohms. Against the nominal impedance, the return loss shall be at least 20 db. Table 3.2.2.5.1.2.6 indicates application of the balanced and unbalanced impedances to number of channels in radio relay systems, and the frequency allocations of the baseband.

3.2.2.5.1.2.5 *Intermediate Frequency Interface.* The IF portion of radio relay equipment may provide an interface in some system designs. The following parameters shall be met:

(a) Frequency—70 mc.

(b) Impedance and Return Loss—The impedance shall be 75 ohms, unbalanced, and shall have a return loss against the nominal impedance of at least 20 db.

(c) Signal Levels In the receiving direction, the IF output voltage shall to equal to or greater than 0.5 volt, rms; in the transmitting direction, the required IF input voltage shall not exceed 0.3 volt, rms.

3.2.2.5.1.2.6 *Modulation Plan.* (Under consideration See table 3.2.2.5.1.2.6.)

3.2.2.5.2 *Noise and Interference.*

3.2.2.5.2.1 *Total Noise.* The total noise from all sources appearing in any channel shall not exceed a median value of 25,000 pwp (38 dba F1A weighted) during the worst hour of the month of poorest transmission.

3.2.2.5.2.2 *Allocation.* The following allocation of allowable median noise to various parts of the DCS Reference Circuit shall be followed unless different trade-offs are dictated by particular requirements:

(a) Multiplex equipment .... 5, 000 pwp

One Link

Channel translation	345 pwp
Group modem equipment (2)	140 pwp
Supergroup modem equipment (3)	180 pwp
Through group filter and AGC equipment (3)	150 pwp
Total for one link	815 pwp
Total multiplex equipment for six links	4, 890 pwp

(b) The 20,000 pwp median noise assigned to the transmission media shall be derived in equal parts from the two principal sources, thermal and intermodulation, thus allowing 10,000 pwp thermal and 10,000 pwp intermodulation noise

Table 3.2.2.5.1.2.6. DCS Modulation Plan

Basic (12-channel) Group: (Under consideration)

Basic (60-channel) Supergroup: Five groups translated (as upper sidebands) to occupy the basic supergroup frequency band 312 to 552 kc.

Number of channels	Freq. limits band occupied by tel. chan. (kc) (note 2)	Freq. limits baseband (kc)	Nominal impedance baseband (ohms)	Power level per chann.		Continuity pilot freq. (kc) (note 1)
				Input (dbm0) ≤	Output (dbm0) ≥	
24	12–108	12–108	135 bal	−45	+4.5	116 (or 119)
60	12–252	12–252	135 bal	−45	+1.75	304 (or 331)
	*60–300	60–300	75 unbal	−45	−15	
120	12–252	12–552	135 bal	−45	+1.75	607 (or 304)
	*60–552	60–552	75 unbal	−45	−15	

Pilots

1. Frequency comparison and control monitoring (Under consideration)
2. Through regulating pilot (Under consideration)

Notes: 1. Frequency stability of continuity pilot shall be better than 5 parts in 10^6.
2. *Bandwidth of white noise spectrum for intermodulation noise measurements.

3.2.2.5.2.3 *Distribution.* A time distribution is required since line-of-sight systems are subject to fading, causing the noise power to increase considerably from time to time. Excessive noise caused by unsatisfactory radio transmission shall not exceed 316,000 pwp (49 dba F1A) at zero relative level, 1-minute mean value more than 0.01% of the time, during the month of poorest transmission.

3.2.2.5.2.4 *Interference.* Unintentional interference shall not be allowed to exceed a level as follows when the channel is used for active speech transmission:

(a) Cochannel 24 dba0
(b) Adjacent channel 21 dba0
(c) Unidentified 21 dba0

3.2.2.5.3 *Transmission Properties.* Standards for the determination of transmission loss are given in 3.2.2.5.4. In order to facilitate the comparison of results, the following is given so that transmission loss determinations may be presented in a uniform manner:

3.2.2.5.3.1 *Long-Term Variations.* The hourly median transmission loss not exceeded during 50, 90, 99, and 99.9 percent of all hourly medians of the period of reference shall be determined. The period of reference shall not be less than 1 month. Data shall also be given to show the distribution of the hourly median transmission loss over the entire year.

3.2.2.5.3.2 *Data Presentation.* The statistical results of the transmission loss determinations shall be displayed on probability paper. The transmission loss shall be plotted along the ordinate and expressed in decibels; the percentage of time shall be plotted along the abscissa, with a scale following the Gaussian probability law, with percentages increasing from left to right.

3.2.2.5.4 *Transmission Loss Calculations.*

3.2.2.5.4.1 *Radio Reference Atmosphere.* The Standard Radio Reference Atmosphere shall be the three-part model as follows:

(a) The radio refractivity, N, decreases linearly in the first kilometer above the surface; that is,

$$N = N_s + \Delta N(h - h_s), h_s \leq h \leq h_s + 1$$

(b) The radio refractivity, N, equals 105 at 9 km above sea level and the refractivity decreases exponentially between 1 km above the earth's surface, h_s+1, to the value of 105 at 9 km; that is

$$N = N_1 \exp\left(\left(-c(h - h_s - 1)\right)\right), h_s + 1 \leq h \leq 9,$$

where

$$-c = \frac{1}{8 - h_s} Ln \frac{105}{N_1},$$

and

N_1 is the value of N at $h = h_s + 1$.

(c) Above 9 km the refractivity is determined by:

$N = 105 \exp\left(\left(-.1424(h-9)\right)\right), h \geq 9$ km.

N is the radio refractivity.

N_s is the surface value of refractivity.

ΔN is the difference in N values at a height of 1 km above the surface and at the surface.

h is the height above sea level.

h_s is the height of the surface above sea level.

The constants for the standard radio reference atmosphere are given in table 3.2.2.5.4.1 and shall be used in the computation of the basic median transmission loss due to Microwave Line-of-Sight Propogation.

Table 3.2.2.5.4.1. Constants for the Standard Reference Atmosphere

N_s	h_s feet	a' miles	$-\Delta N$	k	a_e miles	c per KM
0	0	3960. 0000	0	1. 00000	3960. 00	0
200	10, 000	3961. 8939	22. 3318	1. 16599	4619. 53	0. 106211
250	5, 000	3960. 9470	29. 5124	1. 23165	4878. 50	0. 114559
301	1, 000	3960. 1804	39. 2320	1. 33327	5280 00	0. 118710
313	900	3960. 1324	41. 9388	1. 36479	5403. 88	0. 121796
350	0	3960. 0000	41 5530	1. 48905	5896. 66	0. 130579
400	0	3960. 0000	68 1295	1. 76684	6996. 67	0. 143848
450	0	3960. 0000	90. 0406	2. 34506	9286. 44	0. 154004

Notes a_e is the effective earth's radius and is equal to $a'k$
$a' = a + h_s$ where h_s is the height of the earth's surface above sea level
$a = 3{,}960$ miles

$$c = \frac{1}{8 - h_s} \ln \frac{N_1}{105}$$

3.2.2.5.4.2 *Path Geometry.* The geometrical parameters defined in figure 3.2.2.5.4.2, specifically the path distance, d, and Grazing Angle ψ, shall be determined using the factors of the accuracy specified in 3.2.2.5.7, Siting, and with the effective earth's radius, a_e, defined in table 3.2.2.5.4.1, Constants for the Standard Reference Atmosphere.

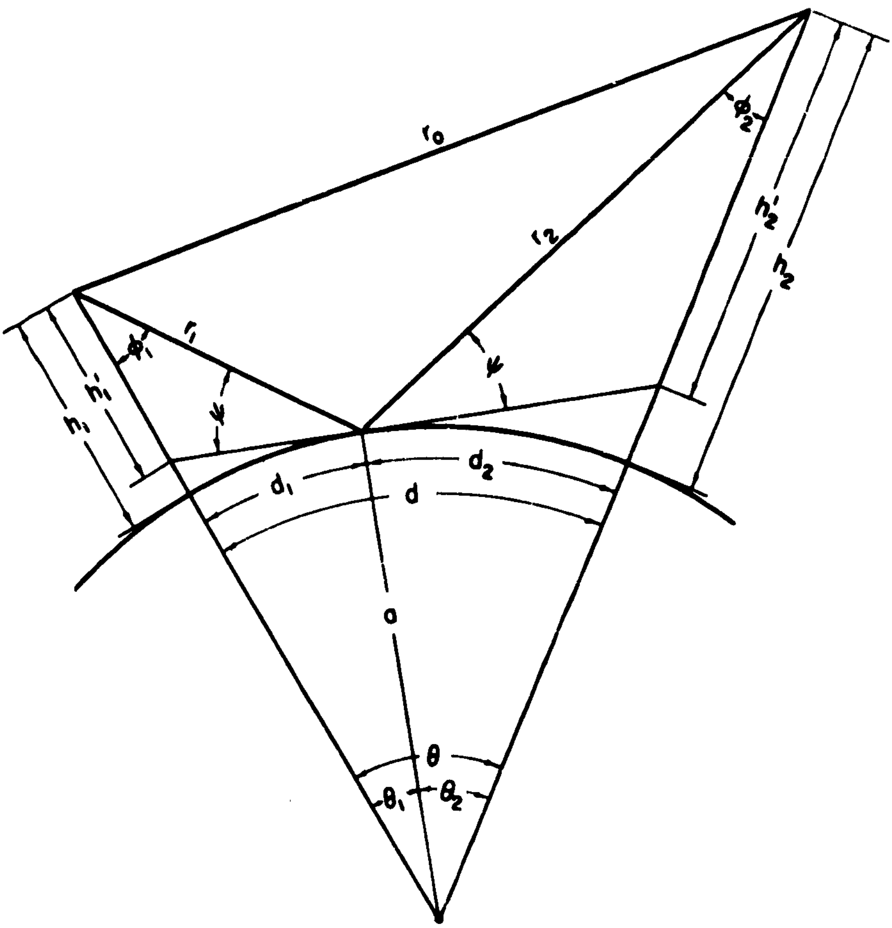


Figure 3.2.2.5.4.2.a. Geometry for W thin-the-Horizon Paths

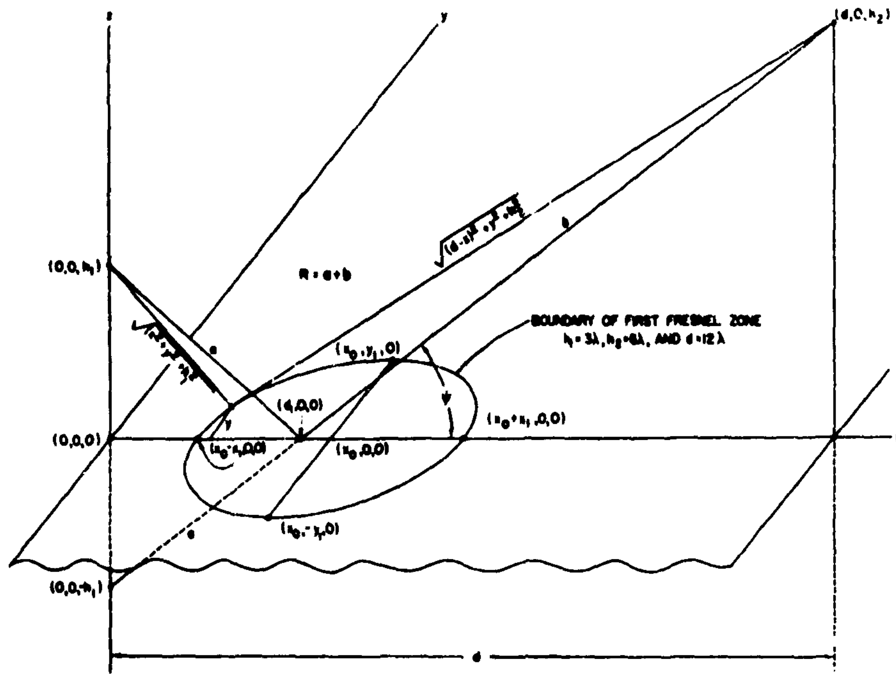


Figure 3.2.2.5.4.2.b. Geometry for Fresnal Zone Calculations

3.2.2.5.4.3 *Transmission Loss.* The transmission loss shall be determined either by (1) computation, or (2) from path loss measurements and computation combined.

3.2.2.5.4.3.1 *Computation.* The basic equation for the computation of transmission loss shall contain, as a minimum, terms showing the effects of frequency, distance, terrain, and meteorological conditions. The computed transmission loss using the basic equation shall be an hourly median value based on the Standard Reference Atmospheres (3.2.2.5.4.1) and on geometrical parameters to the accuracy specified in 3.2.2.5.7. The data shall be presented to show the worst hour worst month loss.

3.2.2.5.5 *Frequency Assignment.*

3.2.2.5.5.1 *Channel Spacing.* The minimum RF channel spacing for any microwave system shall be as follows:

Number of voice channels	*Channel separation*
36	5.6 Mcs
60	11.2 Mcs
120	14.0 Mcs
≥300	29.0 Mcs

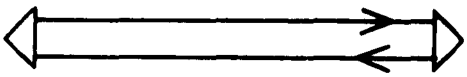
3.2.2.5.5.2 *Transmit-Receive Frequency Separation.*

(a) All of the "go" channels shall be in one-half of the band, and all of the "return" channels shall be in the other half of the band. The terms "go" and "return" are used only to distinguish between the two directions of transmission.

(b) If a transmitter and receiver are operated at the same frequency in the same station, the loss between the transmitter and receiver must be greater than 120 db.

(c) For adjacent radio-frequency channels in the same half of the band, different polarizations shall be used alternately; i.e., the odd-numbered channels in both directions of transmission on a given section shall use H(V) polarization, and the even-numbered channels shall use V(H) polarization.

channels 1, 3, 5....H(V)
channels 2, 4, 6....V(H)



channels 1′, 3′, 5′....H(V)
channels 2′, 4′, 6′....V(H)

(d) In order to prevent interference between the transmit and receive antennas on opposite sides of a station, each channel shall be shifted in frequency (or frogged) as it passes through a repeater station as shown in table 3.2.2.5.5.2(a).

Table 3.2.2.5.5.2 (a). Minimum Shift in Frequency as a Channel Passes Through a Station

Number of voice channels	RF carrier frequency in Mcs	
	2,000 to 4,000	6,000 to 8,000
120 or less	120	161
300 or greater	213	252

(e) The minimum separation between a transmit and receive carrier frequency on a single hop shall be as shown in table 3 2.2.5.5.2(b).

Table 3.2.2.5.5.2 (b). Minimum Separation Between a Transit and Receive Carrier Frequency at a Single Station. (Minimum Guard Channel Width Between Upper and Lower Half of the Allocated RF Frequency Band.)

Number of voice channels	RF carrier frequency in Mcs	
	2,000 to 4,000	6,000 to 8,000
60-120	49	30
>120	68	44.5

3.2.2.5.5.3 *IF Interference.* The center frequency and the channel spacing of the RF carrier frequencies shall be chosen so as to prevent interference due to certain harmonics of the shift frequency. That is, harmonics cannot occur at f_n, the channel frequency, or at $f_n \pm 70$ Mcs when the IF is 70 Mcs.

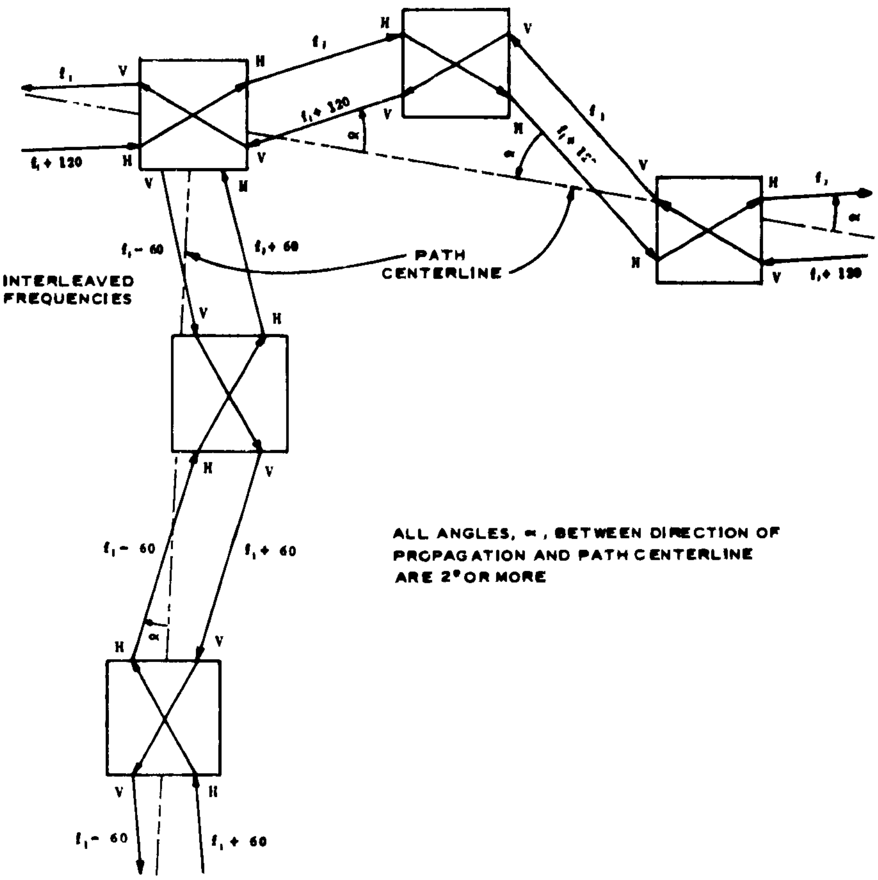


Figure 3.2.2.5.5.4.b. Recommended Plan for Large Channel Capacity (>120) Assuming All Channels Are Being Used in Every Hop

may be minimized by using Plan 1 of figure 3.2.2.5.5.4.a where alternate channels are used on alternate hops.

3.2.2.5.6 *Equipment Performance.*

3.2.2.5.6.1 *Antennas.* The antennas used at each station shall be the broad band, high gain type, capable of operating satisfactorily on any frequency in the specified band of operation.

3.2.2.5.6.1.1 *Characteristic Impedance.* The characteristic impedance shall be 50 ohms.

3.2.2.5.6.1.2 *Voltage Standing Wave Ratio (VSWR).* The VSWR shall not exceed 1.2 to 1.

3.2.2.5.6.2 *Transmission Line.* The transmission line shall be capable of transmitting the required RF power with the characteristics listed below. The use of coaxial connectors shall be held to a minimum. The length of any transmission line shall be held to a minimum commensurate with good engineering practice and shall not exceed 200 feet in any case.

3.2.2.5.6.2.1 *Characteristic Impedance.* The characteristic impedance shall be 50 ohms.

3.2.2.5.6.2.2 *Voltage Standing Wave Ratio (VSWR).* The VSWR shall be less than 1.05 to 1 when terminated in the characteristic impedance of the line.

3.2.2.5.6.3 *Receiving Equipment.*

3.2.2.5.6.3.1 *RF Input Impedance.* The RF input impedance shall be 50 ohms.

3.2.2.5.6.3.2 *Frequency Stability.* The center frequency of the receiver shall be controlled to within 0.01% for all operating conditions.

3.2.2.5.6.3.3 *Image and Out-of-Band Frequency Rejection.* Image and out-of-band frequencies shall be rejected by at least 60 db.

3.2.2.5.6.3.4 *Intermediate Frequency Characteristics.* The nominal center value of the intermediate frequency shall be 70 mc. The output impedance shall be 75 ohms, unbalanced. In the receiving direction, the IF output voltage shall be equal to or greater than 0.5 volt, rms; in the transmitting direction, the required IF input voltage shall not exceed 0.3 volt, rms. The transmission amplitude characteristic shall be uniform within ±1.5 db over the intermediate frequency band.

3.2.2.5.6.4 *Transmitting Equipment.*

3.2.2.5.6.4.1 *RF Output Impedance.* The RF output impedance shall be 50 ohms.

3.2.2.5.6.4.2 *Carrier Frequency Stability.* The carrier frequency shall be controlled to within 0.01% for all operating conditions.

3.2.2.5.6.4.3 *Spurious Emission Suppression.* Spurious emissions occurring outside the assigned band shall be suppressed 80 db or more below the carrier output.

3.2.2.5.6.4.4 *Preemphasis Characteristic.* As far as is practical, systems should conform to the following characteristics:

3.2.2.5.6.4.4.1 *Frequency Deviation Without Preemphasis.*

Maximum number of channels	*Rms deviation per channel (kcs)*
24	35
60	50, 100, 200
120	50, 100, 200
>300	200

3.2.2.5.6.4.4.2 *Frequency Deviation With Preemphasis.* Where preemphasis is used, the preemphasis characteristic shall be such that the effective (rms) deviation due to the multichannel signal is the same with and without preemphasis.

Note. It is recommended that the preemphasis characteristics be that obtained by the network given in CCIR Recommendation No. 275 and contained in the addendum to Tropospheric Scatter paragraph.

3.2.2.5.6.5 *Multiplexing Equipment.* Characteristics of the multiplexing equipment are specified in 3.2.2.5.1.1, Transfer Function Parameters, 3.2.2.5.1.2, Interface Parameters, and 3.2.3.3. Performance Standards for Frequency Division Channeling Equipment.

3.2.2.5.6.6 *Test Procedures.* Test procedures, where applicable, are given in chapter 5.

3.2.2.5.7 *Siting.* The determination of path parameters shall be in three parts: (1) the preliminary determination, (2) the site survey, and (3) the final determination.

3.2.2.5.7.1 *Preliminary.* When a preliminary study is made, prior to actual site survey, such that several alternate sites are selected, maps shall be used with a scale of at least 1 in 250,000 with contours to the nearest 20 meters. Distance shall be determined to the nearest mile.

3.2.2.5.7.2 *Site survey.* The selected site(s) shall be surveyed, such that a terrain profile may be constructed showing the distances and elevations along the path azimuth, with an accuracy not less than the following:

(a) Coordinates to third order accuracy.

(b) Elevations to the nearest 2 meters.

3.2.2.5.7.3 *Final Determination.* The final path parameters (path profile) shall be determined with an accuracy not less than the following:

(a) All distances to 0.1 mile.

(b) All azimuths to 10 seconds.

(c) Maps utilized shall have a scale of 1 in 25,000 with contours at 5-meter intervals. In areas where maps to this scale are not available, a scale of up to 1 in 100,000 with contours at not more than 30-meter intervals may be used.

3.2.2.5.7 *Hazards.* The following conditions shall apply regarding hazards to personnel and equipment.

(a) The area in the vicinity of the antenna(s) shall be restricted to prevent inadvertent entry so that personnel not be exposed to either continuous or intermittent power levels in excess of 0.01 watt per square centimeter, average power.

(b) The area in the vicinity of the high power equipment shall be restricted to prevent inadvertent entry so that personnel not be exposed to X-radiation exceeding 2.5 milliroentgens per hour or 1,000 milliroentgens during a 40-hour week.

(c) Fuel storage areas shall not be exposed to RF power in excess of 5.0 watts per square centimeter, peak power.

(d) Power levels constituting hazards to explosives have not been firmly established.

(e) Power levels constituting hazards to equipment have not been firmly established.

3.2.2.5.8 *Systems Performance.* For analysis purposes, it is convenient to consider systems performance in terms of (1) Single Hop Performance, and (2) Tandem Hop Performance

3.2.2.5.8.1 *Single Hop Performance.*

3.2.2.5.8.1.1 *Noise in a Real Circuit.* The psophometrically weighted noise power, excluding multiplex equipment noise, at a point of zero relative level in the audio channels of a real line-of-sight hop of length L nautical miles, where L is less than 1,000 nautical miles and whose composition does not differ appreciably from the DCS Reference Circuit, shall not

(a) Exceed $3.33L$ pwp median during the worst hour of the worst month

(b) Exceed 316,000 pwp more than a cumulative $\frac{L}{1{,}000} \cdot 0.002\%$ of the time during the worst month.

It is not expected that all hops will meet the noise limit specified in (a) above; some hops will be better and some worse. However, the cumulative noise power from all hops in tandem within the 1,000-nautical mile reference link shall meet the specified performance criteria.

3.2.2.5.8.1.2 *Performance tests.* After all equipment has been properly installed and adjusted, and transmission levels have been properly set, performance tests shall be made on each hop to determine the quality of transmission. These tests shall be in two parts: (1) local tests, and (2) transmission system tests.

3.2.2.5.8.1.2.1 *Local tests.* The local tests, from multiplex input to multiplex output including the radio transmitter and receiver, shall include but not be limited to those tests required to establish the characteristics specified in 3.2.2.5.1.1. Transfer Function Parameters. Test procedures are given in chapter 5.

3.2.2.5.8.1.2.2 *Transmission System Tests.* The transmission system tests, including the propagation medium shall include as a minimum the measurement of stability of the net gain or loss in the baseband and total noise including intermodulation noise. (See 3.2.2.5.8.3.)

3.1.1.5.8.1.2.3 *Duration of Measurement.*

3.2.2.5.8.1.2.3.1 *Continuous Uniform Spectrum.* Total noise measured in each direction in each hop with a continuous uniform spectrum signal shall be of a duration necessary to establish a correlation between the total channel noise and the received signal power, but in any case shall not be less than 72 hours valid data.

3.2.2.5.8.1.2.3.2 *Received Signal Level.* The received signal power in each direction in each hop shall be recorded continuously for a period not less than 30 days (preferably 6 months). This data shall be presented to show the signal power exceeded 0.1%, 1%, 10%, 50%, 90%, 99%, and 99.9% of all hours during the period of measurement. The correlation between the received signal power and total channel noise shall be shown.

3.2.2.5.8.1.2.3.3 *Noise in Actual Traffic.* The total noise measured in actual traffic in each hop in each direction after the system is in operation shall be recorded continuously for a period not less than 30 days (preferably 6 months).

3.2.2.5.8.2 *Tandem Hop Performance.*

3.2.2.5.8.2.1 *Noise in a Real Circuit.* The psophometrically weighted noise power, excluding multiplex equipment noise, at a point of zero relative level in the audio channels of a real line-of-sight system of length L nautical miles, where L is between 1,000 and 6,000 nautical miles, and whose composition does not differ appreciably from the DCS Reference Circuit shall not

(a) Exceed [7] $3.33L$ pwp median during the worst hour of the worst month.

(b) Exceed 316,000 pwp more than a cumulative $\frac{L}{6,000} \times 0.01\%$ of the time during the month of poorest transmission.

[7] It is assumed that at the demodulation points of a real circuit, the audio channels, groups, and supergroups are interconnected at random. In particular, it is assumed that the noise coming from the different sections is power additive

3.2.2.5.8.2.2 *Performance Tests.* Tandem hop performance tests over the entire system shall include as a minimum the measurement of stability of the net gain or loss in the baseband and total noise including intermodulation noise.

3.2.2.5.8.2.2.1 *Duration of Noise Measurement.* The total noise in each direction in the entire system shall be recorded for a period to provide 72 hours of valid data as soon as practicable after installation.

3.2.2.5.8.3 *Total Noise Measurement.* Total noise, including crosstalk noise, should be measured with a continuous uniform spectrum signal or during actual traffic. Measurement with a continuous uniform spectrum signal is made while the system is not carrying actual traffic and with a white noise signal representing system loading during busy hours; measurement during actual traffic is made in bands just outside the total multiplex band, in actual traffic conditions.

3.2.2.5.8.3.1 *Measurement With Continuous Uniform Spectrum Signal.* It is desirable to be able to measure the performance of radio relay systems used with FDM under conditions closely approaching those of actual operation, without necessarily having FDM equipment installed and connected. For systems with 12 or more channels, it has been established that a white noise signal (a signal with a continuous uniform spectrum) has statistical properties similar to those of a multichannel multiplex signal. This type of test uses a white noise generator producing a spectrum of width corresponding to the multiplex signal it replaces, but with specified gaps produced by stop filters, at the lower and upper edges of the baseband (just within or just outside) and at the center of the baseband. The noise measurements are made in the stop bands, through suitable receiving filters. Specifications are given below for those parameters. They correspond to CCIR Recommendation 294 (Warsaw, 1956—Los Angeles, 1959).

(a) White noise signal spectrum—Table 3.2.2.5.8.3.1 gives the bandwidth for systems with 24 to 600 channels, for the allocations starting at 12 kc at the lower edge.

(b) White noise signal power levels—The power level of the white noise signal is computed according to the following formulas, relative to 1 mw at a point of zero transmission level, where n is the total number of channels in the circuit:

(1) For systems with from 60 to 240 telephone channels:
Power level $= (-1 + 4 \log_{10} n)$ dbm0
(Provisionally applies down to minimum of 12 channels.)

(2) For system with 240 to 600 channels (or more):
Power level $= (-15 + 10 \log_{10} n)$ dbm0

(c) Within the specified band, the rms noise voltage levels measured with a narrow bandwidth of about 2 kc should not vary more than 1 db. Outside this band, the power should drop sharply and be more than 25 db down at all frequencies greater than 10% above and 20% below the band.

(d) Stop and band filters—To clear the measurement channels of white noise, stop band filters are required at the output of the white noise generator. The center frequencies of these filters should be the same as for the measuring channels shown in table 3.2.2.5.8.3.1. Three filters should be used in a given case, including the center channel and either the outside band (OB) or inside band (IB) channels. The attenuation of noise in each stop band at the generator output should exceed 80 db over a band at least 3-kc wide, and should not exceed 3 db at frequencies of $\pm(0.02 f + 4)$ kc, where f is the center frequency in kc. The shape of the filter characteristics should be such that, when all three band stop filters are simultaneously brought into the circuit, the errors in measurement as compared with a measurement carried out with a perfectly uniform source and an indefinitely narrow stopband should not exceed 1 db. Error here means the loss due to insertion of filters, to changes in spectral distribution of thermal and intermodulation noise produced by the insertion, and to other causes.

(e) Measurement filters—Intermodulation noise measurements should be performed in the same bands provided in the particular case, with stop band filters as described in the preceding paragraph. The use of these channels is preferred for special tests, calibration, etc. The effective bandwidth of the measuring filters in the receiving equipment should be designed to be narrow enough to provide satisfactory measurements, taking into account the possibility of stop band filter attenuation as low as 3 db at the frequencies $\pm(0.02 f + 4)$ kc with respect to the center frequencies as allowed in the stop band filter requirements.

(f) Additional or alternative measuring channels—These may be used as required by circumstances.

(g) Noise power ratio (NPR) or slot noise power ratio is the ratio of the noise power appearing in a measurement channel with the corresponding stop band filter first out of the circuit and then in the circuit. The change in level is independent of the precise width of the measurement channel.

3.2.2.5.8.3.2 *Measurement of noise in actual traffic.* Once a radio relay system is placed in service carrying FDM channels, it may be difficult or impossible to withdraw it from traffic at will for measurement of noise by the use of white noise signals. It is therefore desirable to specify measurement channels outside but reasonably close to the total bandwidth of the multiplex signal, in order to measure the intermodulation products due to the nonlinearity of the system. It is desirable to measure noise in a channel just above the multiplex band, since this is generally more sensitive to changes of thermal and intermodulation noise in the RF and IF parts of the equipment. On the other hand, measurements in a channel below the multiplex band are more sensitive to changes in the modulators and demodulators. It is usually necessary to use stop band filters at the input of a system to minimize noise on the incoming circuit in the bands occupied by the measuring channels. The following requirements are derived from CCIR Recommendation 293 (Los Angeles, 1959).

(a) Stop band filters—The attenuation of the stop band filters at the input of the system should exceed 50 db over a minimum frequency band $\pm(0.005 f+2)$ kc, where f is the center frequency of the measuring channel in kc. The additional attenuation caused by the insertion of the stop filters at the lower edge and at the upper edge of the total multiplex band should not exceed 0.3 db referred to the additional attenuation caused in the center of the multiplex signal band. The center frequencies of the noise measuring channels are given in table 3.2.2.5.8.3.1. When the center frequency is 10 kc, the minimum frequency band is to be ± 1 kc instead of the band calculated according to the formula given.

(b) Measurement filters—The characteristics of the measurement filters, the center frequencies of which are given in table 3.2.2.5.8.3.1 should be designed to be sufficiently narrow to give satisfactory measurements, taking into account the characteristics of the band stop filters.

(c) Continuity pilots—Frequencies given in table 3.2.2.5.8.3.1 for continuity pilots agree with the central frequencies of the noise measuring channels above the multiplex band. It may be useful to combine the evaluation of the power of the continuity pilot with the measurement of the noise around it.

(d) Filter designs—It is desirable that design of band stop and measuring filters should enable them to be used both for maintenance measurements and for measurements of white noise.

(e) Disconnection of certain channels—In certain telephone channels, and in combinations of them, harmonic distortion may be produced. This may make it necessary to leave these channels disconnected (for example, if the second or third harmonics coincide with the central frequencies of the noise measuring channels).

Table 3.2.2.5.8.3.1. Parameters for radio relay systems

Number of channels	Freq. limits band occupied by tel. chan. (kc) (note 3)	Freq. limits baseband (kc)	Continuity pilot freq. (kc) (note 1)	Noise measuring channels center frequencies in kc						
				Actual traffic		White noise (Note 2)				
						Lower		Center	Upper	
				Below	Above	OB	IB		IB	OB
24	12–108	12–108	116 (or 119)	10	116 (or 119)					
60	12–252	12–252	304 (or 331)	10	304	50	70		270	331
	*60–300	60–300		50	331					
120	12–252	12–252	607 (or 304)	10	607	50	70	270	534	607
	*60–552	60–552		50	607					
300	*60–1300 64–1296	60–1364	1499	50	1499	50	70	534	1248	1499
600	*60–2540 *64–2660	60–2792	3200	50	3200	50	70	1248	2438	3200

NOTES 1. Frequency stability of continuity pilot should be better than 5 parts in 10^5.
2. Lower and upper measuring channels may be either outside (OB) or inside (IB) the band of white noise signal.
3. *Bandwidth of white noise spectrum for intermodulation noise measurements.

3.2.3 *Wire Systems.*

3.2.3.1 *Transmission Modes.* The transmission modes encompassed in these specifications consist of standard long-distance wire configurations and their associated terminal and intermediate equipments.

3.2.3.1.1 *DCS Reference Circuit (Overall Wire System)*—The composition of the DCS Wire Reference Circuit coincides with that of the DCS Wideband Reference Circuit described in paragraph 3.2.1. Each audio-to-audio link is defined as having a maximum of one set of channel translating equipment, two sets of group translating equipment and three sets of supergroup translating equipment. The DCS Wire Reference Circuit is further described in the following paragraphs in terms of its transfer functions and interface parameters. Actual wire circuits which are a part of the DCS shall be designed to have these transfer functions and interface parameters.

3.2.3.1.2 *Transfer Function Parameters.* The transfer function parameters define the properties of the DCS Wire Reference Circuit in terms of circuits utilizing 4-kc channel allocations involving the various distortions, noise, stability, adjustments, and signal level loading. The parameters may be defined within three aspects: overall reference circuit, transmission medium (including repeaters), and multiplex equipment (for one nominal 1,000 nm link).

3.2.3.1.2.1 *Echo Return Loss.* The echo return loss is specified in terms of echo tolerance of circuits terminated in two-wire or four-wire switching centers or instruments.

(*a*) The echo return loss of two-wire terminating circuits is specified as not less than 13 db at the terminal switching center.

(*b*) The echo return loss of four-wire circuits with two-wire end links is specified as not less than 27 db on the two-wire end link.

3.2.3.1.2.2 *Insertion Loss Frequency.* The response characteristics are stated in terms of insertion loss referred to the 1,000 cps loss. Thus a positive figure denotes lower response and a negative figure indicates a higher response relative to 1,000 cps.

Single Link Channel Frequency Response

The frequency response referred to 1,000 cps for the multiplex equipment (1 link only) shall be as follows:

600–2,400 cps	+0. 7	−0. 7 db
400–3,000 cps	+1. 5	−0. 7 db
300–3,400 cps	+3. 0	−0. 7 db

Overall Circuit Frequency Response

The frequency response referred to 1,000 cps for the overall 6,000-nautical mile circuit shall be as follows:

600–2,400 cps	+4. 0	−4. 0 db
400–3,000 cps	+9. 0	−4. 0 db
300–3,400 cps	+18. 0	−4. 0 db

3.2.3.1.2.3 *Group Delay.* The overall group delay of the 6,000-nautical mile reference circuit shall not exceed 350 milliseconds.

3.2.3.1.2.4 *Envelope Delay Distortion.* The envelope delay distortion (differential time delay between any two frequencies between 1,000 and 2,600 cps) shall not exceed 1,000 microseconds over the 6,000-nautical mile reference circuit, or 160 microseconds for the multiplex equipment of one link back to back. Delays are taken to be directly additive.

3.2.3.1.2.5 *Noise.* The following noise figures are psophometrically weighted (dba F1A weighted) and correspond to a mean noise power, when referred to a zero level, of 25,000 picowatts. Of this 25,000 picowatts, 20,000 are assigned to the line equipment and 5,000 are assigned to be divided up among the multiplex equipment.

(a) The total weighted noise from all sources on the worst channel of any system combined from six links in tandem over 6,000 nautical miles from end to end shall not exceed a mean figure of −46 dbmOp (38 dbaO) in any hour, nor −35 dbmOp (49 dbaO) for not more than 0.01 percent of any month.

(b) Standards for impulse noise are under investigation.

3.2.3.1.2.6 *Harmonic Distortion.* Harmonic or in-channel distortion shall not exceed −40 dbmO for one set of multiplex equipment.

3.2.3.1.2.7 *Circuit Impedance.* At the audio points where different systems are interconnected, the nominal impedance should normally be 600 ohms ±10 percent essentially resistive and provide a return loss of 26 db. The same shall apply to switching centers having different nominal impedances where encountered.

3.2.3.1.2.8 *Gain Change.* A measure of channel amplitude limiting is the gain change for an output level increase. To define the range below which there should be minimal channel limiting, and above which limiting should increase sharply to prevent overloading of common amplifiers, channel limiting requirements are as follows:

(a) Gain change for an output level increase from zero dbmO to +3.5 dbmO shall not be over 0.35 db.

(b) Gain change for an output level increase from zero dbmO to +12 dbmO shall be at least 5 db.

3.2.3.1.2.9 *Net Loss Variation.* The net loss variation due to one set of multiplex audio-to-audio, back-to-back, shall not exceed ±0.2 db. Allowing for variations due to the transmission medium, the overall variation allowable for the 6,000-nautical mile reference circuit shall be ±2.0 db.

3.2.3.1.2.10 *Level Adjustability.* To hold system misalignment to reasonable limits, it shall be possible to adjust the level of test signals to ±0.5 db, particularly at interfaces in the system.

3.2.3.1.2.11 *Maximum Overall Change in Audio Frequency.* Any audio frequency entering a channel of the reference circuit shall be reconstituted at the other end with an error not exceeding ±2 cps.

3.2.3.1.2.12 *Stability of Multiplex Frequency Generator.* The accuracy of the initial adjustment of the master oscillators controlling the various carrier frequencies in the multiplex equipment shall be 2 parts in 10^8 of the selected frequency. The rate of frequency drift shall not exceed 2 parts in 10^7 per month. The change in frequency on changeover from the operating to the standby oscillator shall not exceed 4 parts in 10^8, due to adverse combinations of 10 percent changes in supply voltages. Means shall be provided to compare frequencies of master oscillators in the same station and between different stations, to an accuracy of 1 part in 10^7.

3.2.3.1.2.13 *Single Tone Interference.* Single frequency tones shall not exceed a level of 24 dbaO when the channel is used for active speech transmission.

3.2.3.1.2.14 *Data, Telegraph and Speech Signal Levels.* In systems with many channels, with some channels loaded with voice currents, and others with data or telegraph signals, the levels of the latter shall be determined in the following manner to maintain established loading factors for the common amplifiers. When two or more data or telegraph channels are operated over the same voice channel, they shall be operated at still lower levels to produce equivalent loadings. Data or telegraph signals with FSK modulation produce constant power loading, while AM systems operated at teletypewriter speeds or higher, effectively load the voice channel about 3 db less, and hence may be set at levels 3 db higher than FSK. The maximum levels for signal tones in a voice channel shall be—

FSK .... −13 dbmO
AM .... −10 dbmO

For more than one channel per voice channel, these levels shall be reduced by ($10 \log_{10} n$) db, where n is the number of subchannels, or 3 db lower each time the number of subchannels is doubled. The mean absolute power at zero relative level for speech plus signaling currents over a telephone channel shall be −15 dbmO. It is anticipated that in a system with no voice traffic, the data on telegraph loading levels may be increased.

3.2.3.1.2.15 *Test Procedures.* Test procedures, where applicable, are given in chapter 5.

3.2.3.2 *Subsystem Transmission Modes.* This section specifies the performance of wire and cable subsystems that are combined to form a transmission system. With subsystem performance standards, as specified, and with careful consideration given to the length and quality of each subsystem, those of inferior performance matched with those of superior performance can be combined so that the overall performance will be met. (See figure 3.2.3.2.)

3.2.3.2.1 *Open Wire.* The open-wire subsystem performance requirements are specified by the following parameters:

(a) Capacity of the subsystem
(b) Frequency allocation
(c) Noise
(d) Crosstalk
(e) Repeater gain and spacing

3.2.3.2.1.1 *Capacity of the Subsystem.* The subsystem shall provide 1 to 12 telephone channels on one open-wire pair. A number of subsystems may be operated on one-pole line.

3.2.3.2.1.2 *Frequency Allocation.* The line frequency shall be different for the two directions of transmission and shall be separated at repeaters and terminals by directional filters. The line frequencies for single subsystems shall be 36 to 84 kc in the West to East direction and 92 to 143 kc in the East to West direction. (See figure 3.2.3.2.1.2.)

3.2.3.2.1.3 *Noise.* The permissible weighted noise power at the receiving end of a 1,000 nM 12-channel open-wire hypothetical reference circuit shall not exceed 14,800 picowatts at a point of zero relative level (35.7 dba). Of this quantity, not more than 2,500 picowatts shall be contributed by terminal multiplex equipment, leaving an allowance of 12,300 picowatts for the terminal and intermediate repeaters and the open-wire line. The allowance of 12,300 picowatts may be broken down into, repeater (terminal and intermediate) 1,800, line crosstalk 7,000, atmospheric, power and telegraph interference 3,500. The above figure of 12,300 picowatts for 1,000 nM of line is equivalent to an allowance of 12.3 picowatts per nM compared to 4.9 picowatts per nM for cable systems.

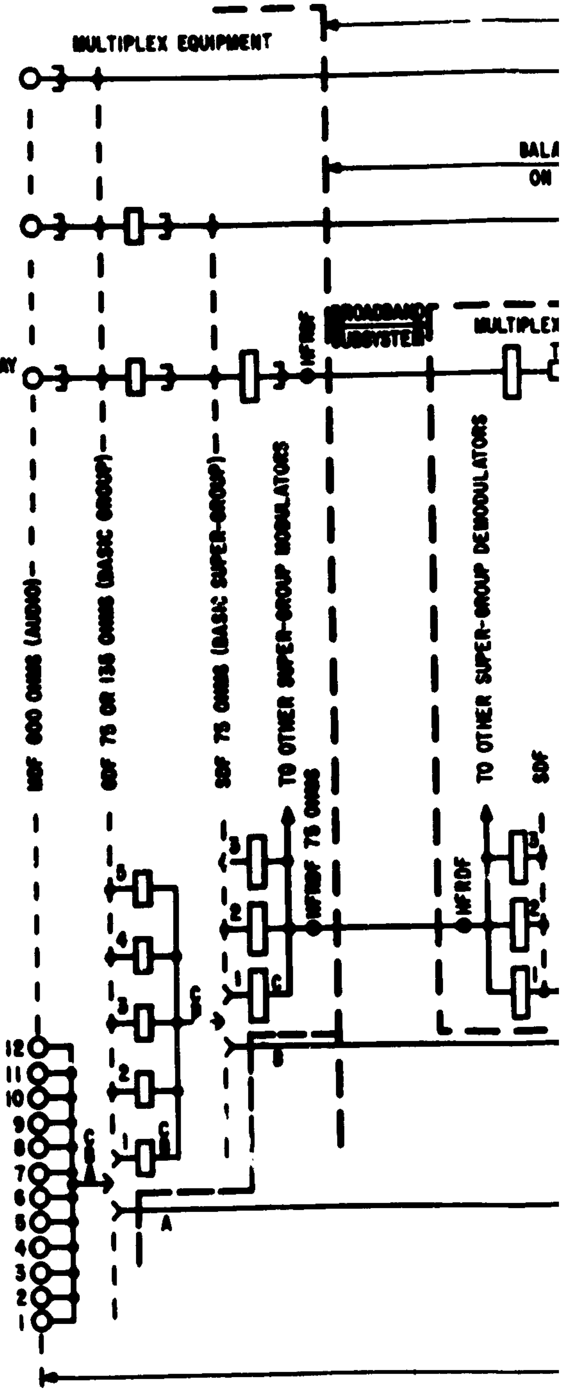
3.2.3.2.1.4 *Crosstalk.* The intelligible crosstalk ratio between any two channels of a 12-channel carrier on open-wire shall not be less than 67 db

HYPOTHETICAL CIRCUIT FOR......

A. OPEN WIRE SYSTEMS

B. SYMMETRICAL CABLE PAIR SYSTEMS

C. BROADBAND RADIO RELAY OR COAXIAL SYSTEMS



LEGEND:

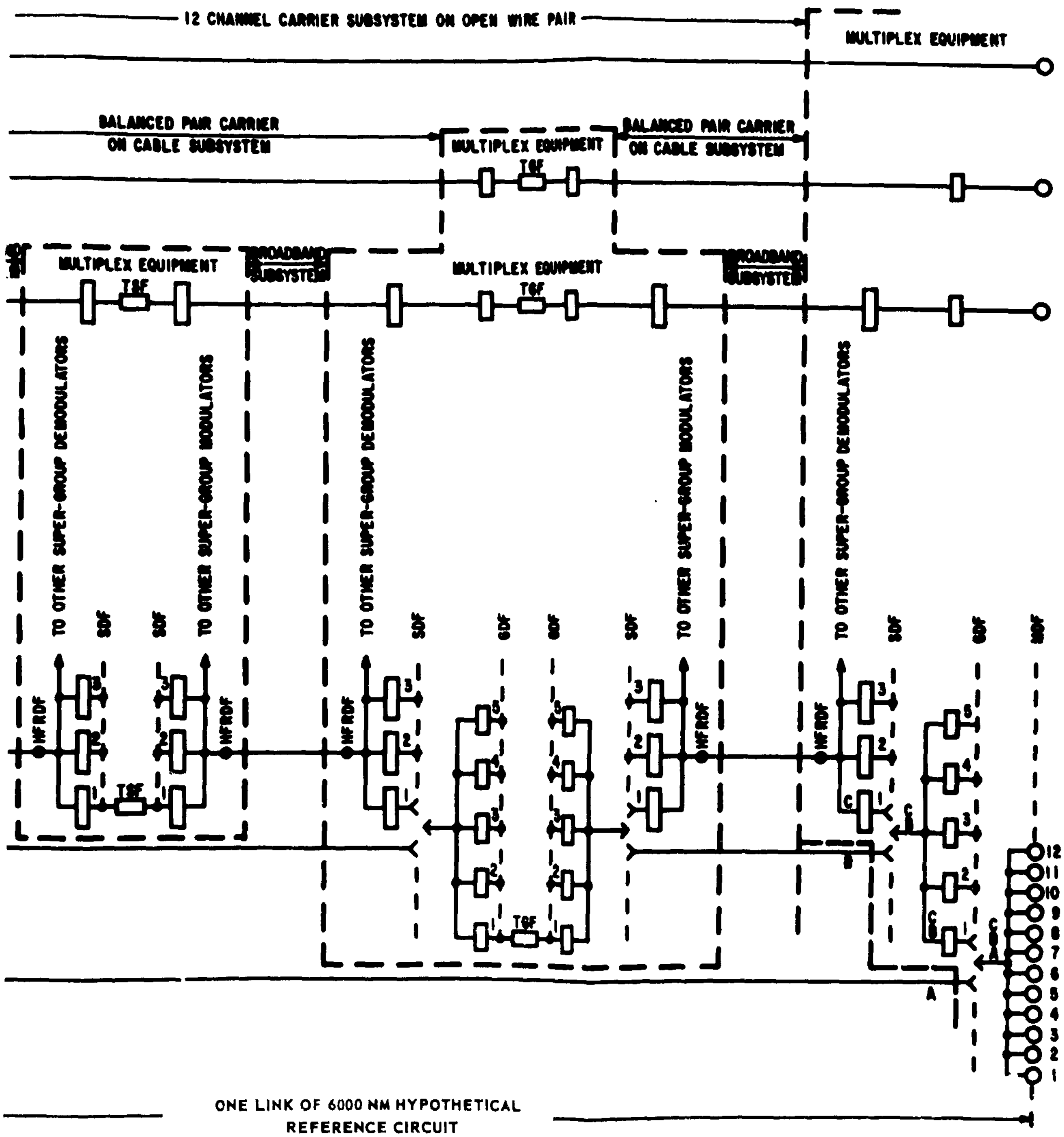
- ○ CHANNEL TRANSLATING EQUIPMENT MULTIPLEX (TRANSLATION OF THE AUDIO FREQUENCY BAND INTO THE BASIC GROUP AND VICE VERSA)
- ▯ GROUP TRANSLATING EQUIPMENT MULTIPLEX (TRANSLATION OF THE BASIC GROUP INTO THE BASIC SUPER-GROUP AND VICE VERSA)
- ▯ SUPER-GROUP TRANSLATING EQUIPMENT MULTIPLEX (TRANSLATION OF THE BASIC SUPER-GROUP INTO THE LINE FREQUENCY AND VICE VERSA)
- MULTIPLE CONNECTION
- TGF THROUGH GROUP FILTER EQUIPMENT
- TSF THROUGH SUPER-GROUP FILTER EQUIPMENT
- GDF GROUP DISTRIBUTION FRAME OR EQUIVALENT POINT
- SDF SUPER-GROUP DISTRIBUTION FRAME OR EQUIVALENT POINT
- MDF MAIN DISTRIBUTION FRAME OR EQUIVALENT POINT
- HFRDF HIGH FREQUENCY REPEATER DISTRIBUTION FRAME OR EQUIVALENT POINT
- —— INTERFACE BETWEEN MULTIPLEX AND SUBSYSTEM
- — — POINT OF FLEXIBILITY

'OTHETICAL CIRCUITS FOR OPEN WIRE SYMMETRIC CABLE PAIR AND BROADBAND SYSTEMS

Illustrating the Definition of the Interface between ndard Multiplex and Sybsystem Equipment, Points of Flexi- ity and the Formation of Systems by the Connection of Multi- x Equipment to Subsystems. Also Shown is the Standard mation of Basic Groups and Supergroups by the Multiplex ipment

A

Figure 3.2.3.2


12 CHANNEL CARRIER SUBSYSTEM ON OPEN WIRE PAIR
MULTIPLEX EQUIPMENT
BALANCED PAIR CARRIER
ON CABLE SUBSYSTEM
MULTIPLEX EQUIPMENT
TGF
BALANCED PAIR CARRIER
ON CABLE SUBSYSTEM
MULTIPLEX EQUIPMENT
TSF
BROADBAND
SUBSYSTEM
MULTIPLEX EQUIPMENT
TGF
BROADBAND
SUBSYSTEM
TO OTHER SUPER-GROUP DEMODULATORS
TO OTHER SUPER-GROUP MODULATORS
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TGF
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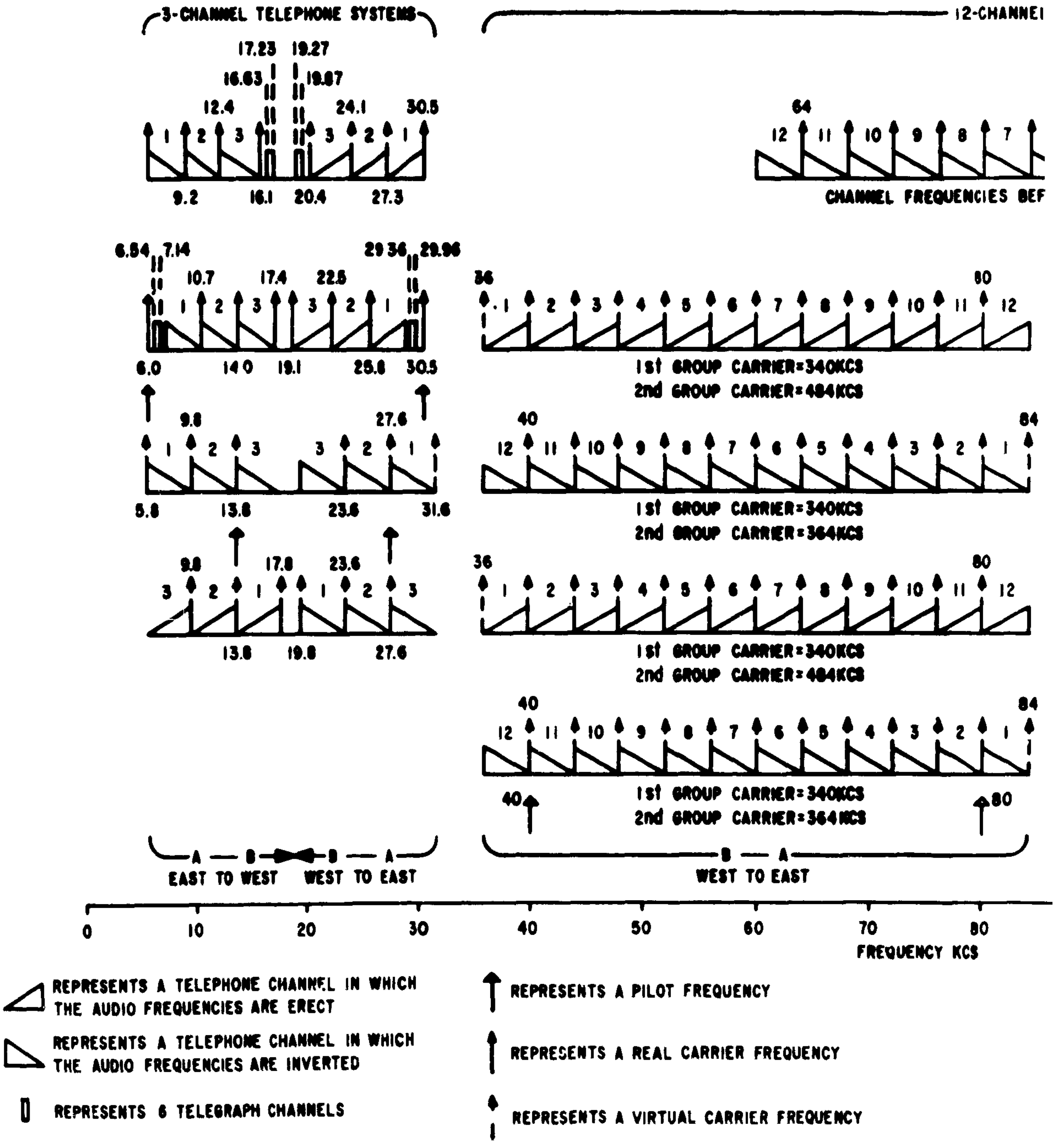
1
ONE LINK OF 6000 NM HYPOTHETICAL
REFERENCE CIRCUIT

Figure 3 - 3 2.

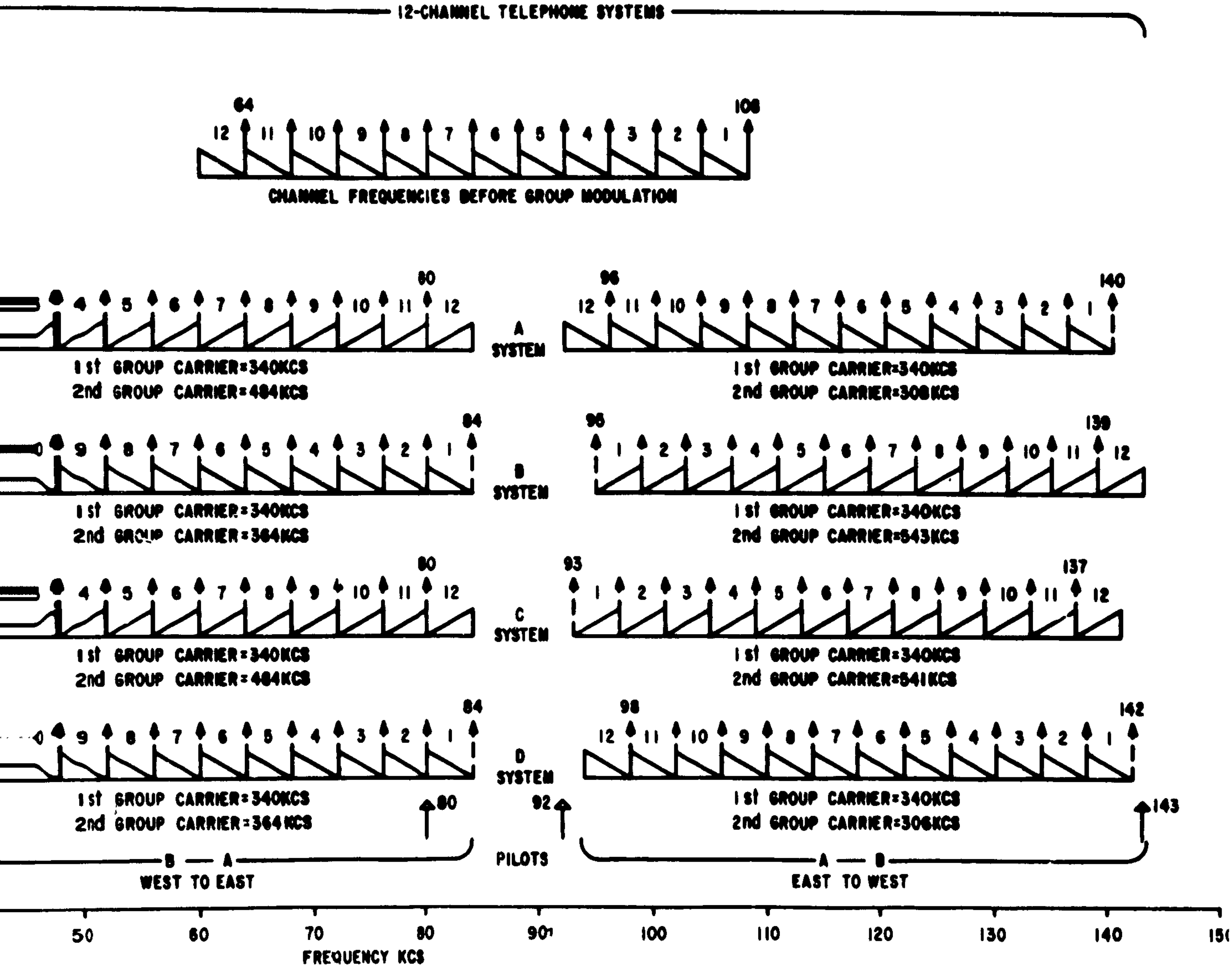
B



OPEN WIRE FREQUENCY ALLOCATION PLANS

Showing Methods of Allocating Frequencies to Minimize Crosstalk Between 12-Channel Subsystems Working on the Same Rou and the Relationship to 3-Channel Systems Using the Same Pair of W

Figure 3.2.3.2.1.2



S A PILOT FREQUENCY

S A REAL CARRIER FREQUENCY

S A VIRTUAL CARRIER FREQUENCY

N PLANS

g Methods of Allocating Frequencies to Minimize
12-Channel Subsystems Working on the Same Route
p to 3-Channel Systems Using the Same Pair of Wires

Figure 3.2.3.2.1.2

B

When more than one carrier system is operated on a pole line, the line cross-talk at carrier frequencies, when the same line frequency allocation is used by the two carriers, shall not exceed the following values: Near-end crosstalk, 42 db per repeater section; far-end crosstalk, 65 db per repeater section.

3.2.3.2.1.5 *Repeater Gain and Spacing.* The spacing of repeaters shall be determined by the permissible noise and crosstalk limits for the repeater section. The maximum level to be transmitted shall not exceed +17 db and the lowest level on the open-wire line should not be allowed to fall below −17 db during the normal weather conditions.

3.2.3.2.2 *Paired and Quadded Cable.* The 12-circuit carrier paired cable and the 12 to 60 channel twin quadded carrier cable performance requirements are specified by the following parameters:

(a) Capacity of Subsystem
(b) Frequency Allocation
(c) Noise
(d) Crosstalk
(e) Repeater Gain and Spacing

3.2.3.2.2.1 *Capacity of the Subsystem.*

(a) The paired cable carrier system shall permit the operation of a 12-circuit carrier on one pair of a nonloaded long distance quality audio cable.

(b) The twin quadded carrier cable shall permit the operation of 60-channel supergroups in increments of 12-channel groups.

3.2.3.2.2.2 *Frequency Allocation.*

(a) For 12-circuit paired carrier cable systems, the frequency allocation shall be 6 to 54 kc in the East-West direction and 60 to 108 kc in the West-East direction.

(b) For 60-channel twin quadded carrier cable systems, the frequency allocation shall be 12 to 252 kc in 12-channel increments of 48 kc.

3.2.3.2.2.3 *Noise.* The weighted noise power of the 12-circuit paired carrier cable system and the 60-channel twin quadded carrier cable system shall not exceed 7,400 picowatts at a point of zero relative level (32.7 dba) for 1,000 nM hypothetical reference circuit. Of this figure 2,500 picowatts shall be allocated to the multiplex and terminal equipment, and 4,900 picowatts to the line and repeaters.

3.2.3.2.2.4 *Crosstalk.*

(a) Each carrier pair of the 12-circuit cable system shall be equipped with balancing networks in each repeater section. The intermediate repeaters shall be of the frequency frogging type. The intelligible crosstalk ratio between any two channels of a 12-channel carrier on paired cable systems or the inter-channel crosstalk on twin quadded cable systems shall not be less than 67 db. Far-end crosstalk ratio between pairs in a repeater section, when the pairs are terminated at their two ends by impedances equal to their characteristic impedance, shall not be less than 65 db per section.

3.2.3.2.2.5 *Repeater Gain and Spacing.* The repeater gain is necessarily dependent upon the type and balance of the cable employed, but in no case shall exceed 56 db for the highest frequency employed on either the 12-circuit paired cable carrier system or the 60-channel twin cable carrier system. Likewise, spacing of the repeaters is dependent upon the same factors, plus physical location. The repeater shall be equipped with line building-out networks to provide for spacing deviations.

3.2.3.2.3 *Coaxial Cable*. The performance requirements of the 4-mc, 6-mc, and 12-mc systems are similar and are dealt with together. The parameters specified are listed as follows:

(a) Capacity of System
(b) Frequency Allocation
(c) Pilot Frequencies
(d) Attenuation vs. Frequency Characteristic
(e) Noise
(f) Crosstalk
(g) Repeater Spacing

3.2.3.2.3.1 *Capacity of the Subsystems*. The number of supergroups and the alternate telephone supergroups plus television channels for each of the subsystems, 4-mc, 6-mc, and 12-mc is as follows:

CAPACITY OF:	4-mc	6-mc	12-mc
Supergroups	16	21	45
Supergroups + TV Channels	16+0 TV	0+1 TV	20+1 TV

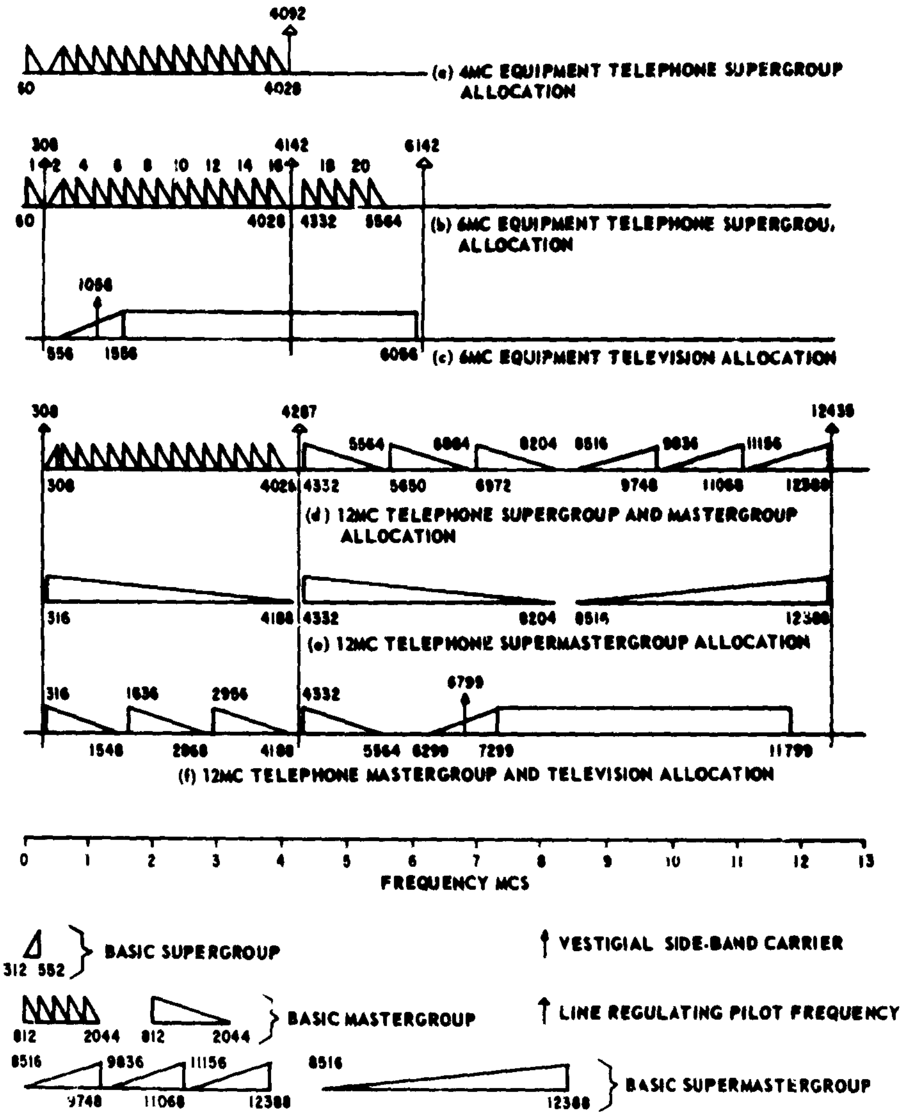
3.2.3.2.3.2 *Frequency Allocation*. The baseband frequency allocations for the three subsystems are shown in figure 3.2.3.2.3.2.

3.2.3.2.3.3 *Pilot Frequencies*. Table 3.2.3.2.3.3 gives the pilot frequencies for the three subsystems.

Table 3.2.3.2.3.3. Pilot Frequencies for the 4-, 6-, and 12-mc Subsystems

Type	Frequency (kc) for—			
	4 mc	6 mc	12 mc	
Pilot frequencies used for automatic line level regulation	4092	308	308	
		4142	4287	
		6142	12435	
Frequency comparison pilot	60	308	308	
			(*)	
Additional line measuring pilots	556	556	560	560
	808	808	808	808
	1056	1056	1304	1304
	1304	1304	1800	1592
	1552	1552	2296	2912
	1800	1800	2792	
	2048	2048	3536	
	2296	2296	5608	5608
	2544	2544	6928	6928
	2792	2792	8248	8248
	3040	3040	8472	8472
	3288	3288	8792	8792
	3536	3536	11112	11112
	3784	3784		

*The first column of pilot frequencies are those required if the baseband allocation in figure 3.2.3.2.3.2. d is used. The second column is used for baseband allocations given in figure 3.2.3.2.3.2.e and 3.2.3.2.3.2.f. The measuring pilots are normally transmitted continuously except those in the TV band when TV program transmissions are in progress.



4 MC, 6 MC, 12 MC BASEBAND FREQUENCY ALLOCATIONS

Showing Telephone and Television Frequency Allocations

Figure 3.2.3.2.3 2

3.2.3.2.3.4 *Attenuation vs. Frequency Characteristic.* At the time of lineup, the power supplies shall be within the specified limits of ±2 percent for 4- and 6-mc systems, and ±1 percent for 12-mc systems. Under these conditions, the spread of the attenuation-frequency response between High Frequency Repeater Distribution Frame (HFRDF) and HFRDF over a distance of 200 nM shall not exceed the value given in table 3.2.5 2.3.4.

Table 3.2.3.2.3.4. Attenuation vs. Frequency Characteristic for 4-, 6-, and 12-mc Subsystems over 200 NM

Frequency range (kc)	Spread (db)		
	4 mc	6 mc	12 mc
60 to 4000	3	3	3
4000 to 5564	-------	4	3
5564 to 6000	-------	6	3
6000 to 12400	-------	-------	(*)

*Under Study (CCITT).

The spread on any supergroup (except 17 to 21) on the 6-mc system shall be less than 1 db.

Supergroups 17 to 21 on the 6-mc system shall have adequate performance or short haul application.

3.2.3.2.3.5 *Noise.* The total mean weighted noise in the band occupied by any standard channel (300 to 3,400 cps) shall not exceed 3 picowatts psophometrically weighted times the length of the cable route in nautical miles. These values shall be measured over the coaxial subsystem between HFRDF points at a point of zero relative level by selective measuring sets, suitably weighted.

3.2.3.2.3.6 *Crosstalk.* The worst value of near-end or far-end crosstalk ratio at the terminals depicted in figure 3.2.3.2.3.6 shall not be less than 85 db at the lowest transmitted intelligence frequency, or 60 db at the highest transmitted intelligence frequency.

3.2.3.2.3.7 *Repeater Spacing.* At the maximum mean annual buried cable temperature of 25° C., the three systems should be designed for the following nominal repeater spacings: 5.2 nM for 4 mc and 6 mc, and 2.6 nM for the 12 mc.

More precisely, the repeater section planning lengths at 10° C. should be as follows: 5.317 nM for 4 mc and 6 mc and 4.9 kM (3.1 nM) for 12 mc.

To calculate the planning length at mean annual buried cable temperature (T), other than 10° C., the following formulas shall be used:

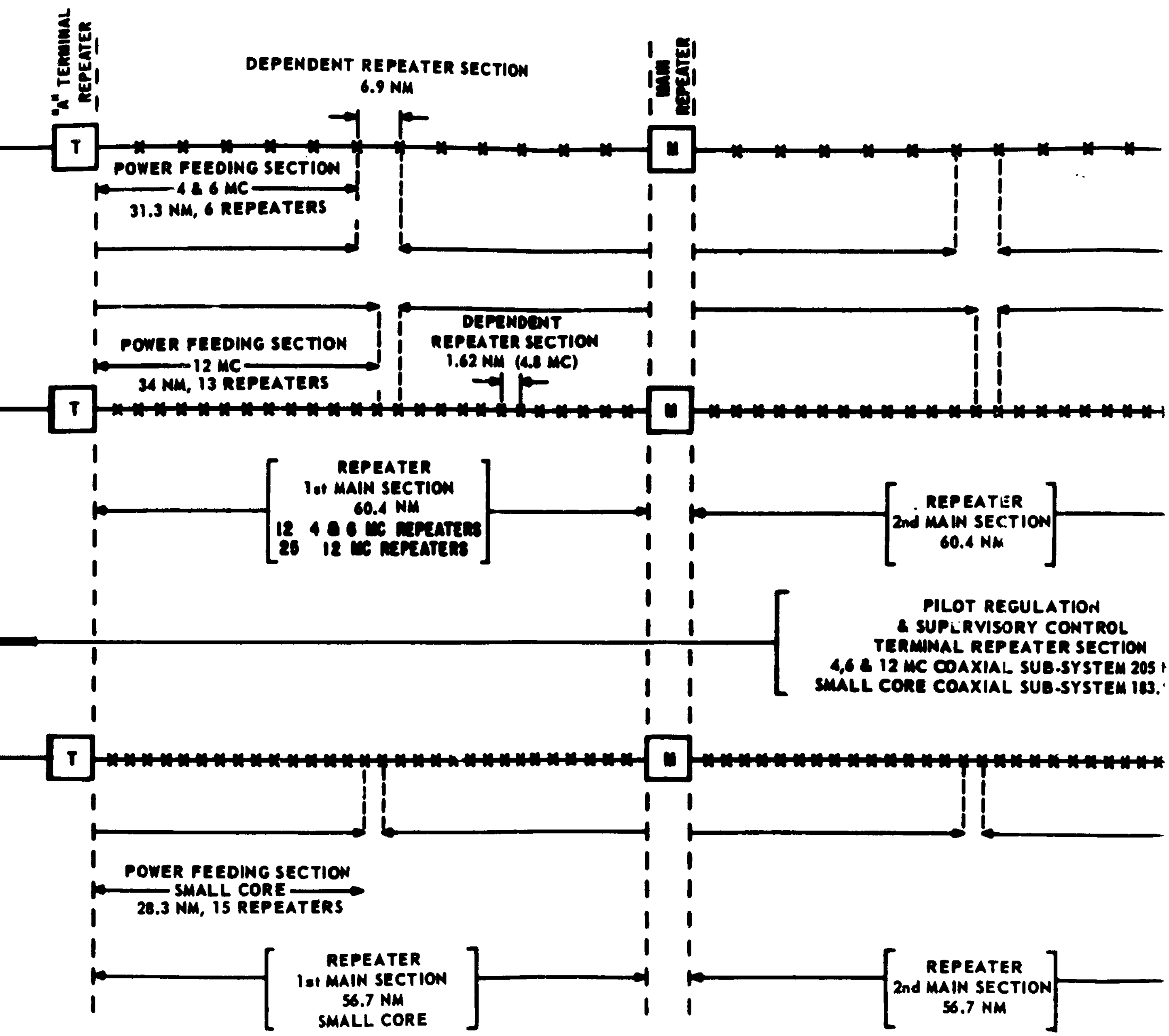
For 4 mc and 6 mc, $5.317\ (1+0.0021(10-T))$

For 12 mc, $2.69\ (1+0.0021(10-T))$

where 0.0021 corresponds to the coefficient of attentuation of 0.21 percent per °C. and T is the temperature in °C. under consideration.

The overall requirements are the same for both 6-mc and 12-mc systems to insure compatibility at the video switching point.

Because video frequencies approaching zero cannot be transmitted over coaxial cable systems, the spectrum of the television subsystem is translated into a suitable range. This process requires vestigial sideband transmit equipment between the video switching point and the HFRDF at the transmit terminal station; and vestigial sideband receive equipment at the receive terminal as indicated in figure 3.2.3.2.3.7. Also, where necessary, emphasis and deemphasis networks are used at each end of the subsystem. It thus differs from the definition of other subsystems.

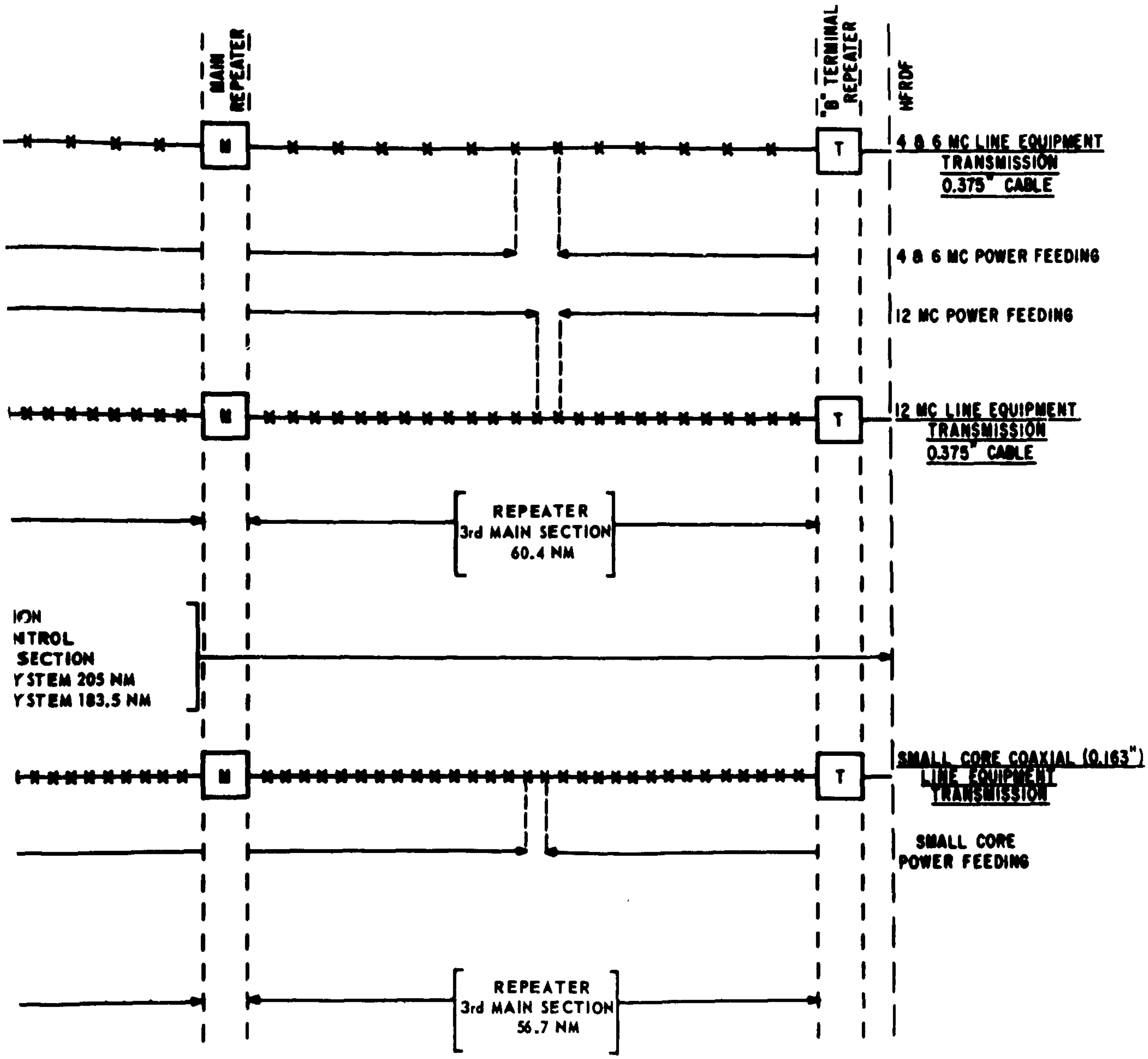


BLOCK DIAGRAM OF COAXIAL CABLE

Showing the Nominal Repeate
Power Feeding Sections for 4, 6 and 12 MC
Inch Cable and 1.3 MC Systems on 0.163 In

A

Figure 3.2.3.2.3.6.

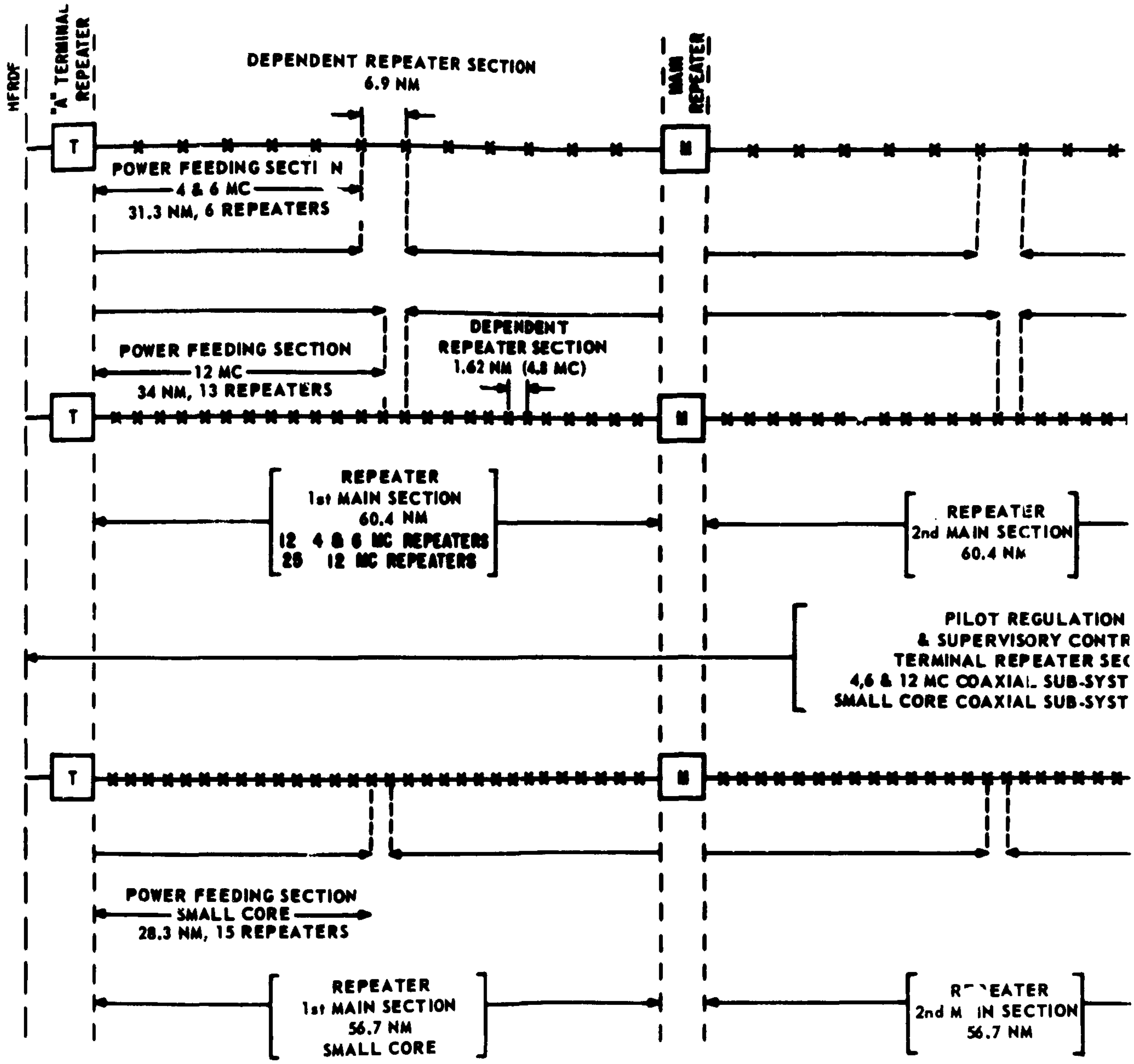


L CABLE SUBSYSTEMS

Repeater Spacings and
nd 12 MC Systems on 0.375
0.163 Inch Cable

3.2.3.6.

B



BLOCK DIAGRAM OF COAXIAL (

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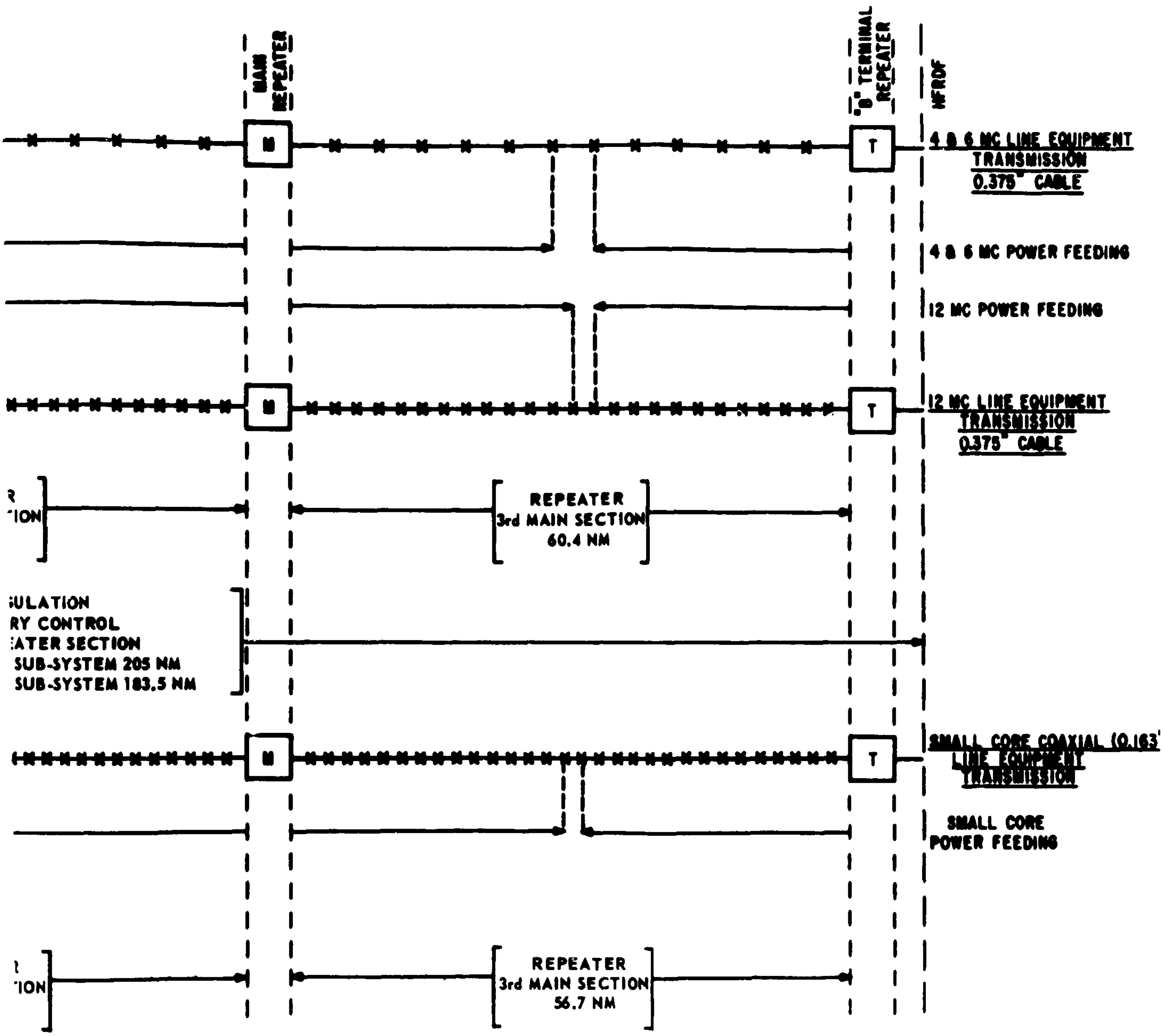
Showing the Nominal R
Power Feeding Sections for 4, 6 and
Inch Cable and 1.3 MC Systems on 0

Figure 3.2.3.

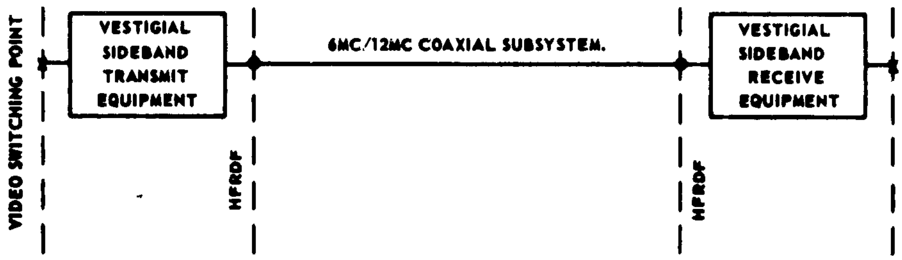


AXIAL CABLE SUBSYSTEMS

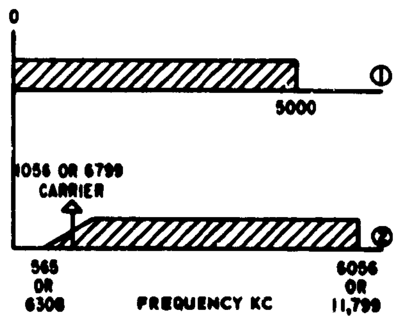
ominal Repeater Spacings and
4, 6 and 12 MC Systems on 0.375
ems on 0.163 Inch Cable

ure 3.2.3.2.3.6.

B



a. BLOCK SCHEMATIC



b. FREQUENCY SPECTRUM

1. VIDEO BASEBAND AT VIDEO SWITCHING POINT 0-5MC

2. LINE FREQUENCY BASEBAND AT HFRDF
(FREQUENCY SPECTRUM DEPENDENT ON SUBSYSTEM)

FM & VESTIGIAL SIDEBAND TELEVISION TRANSMISSION ON COAXIAL CABLE SUBSYSTEMS

Showing the Interface of the Vestigial Sideband Equipment and the Coaxial Subsystem with Frequency Allocation for a 625, 525 or 405 Line Transmission.

Figure 3.2.3.2.3.7.

The following specification, therefore, includes not only the repeatered line with its pilots for regulation purposes, but also such terminal equipment as is mentioned above. The parameters specified for the 6-mc subsystem thus refer to the video switching points.

SUMMARY OF PARAMETERS SPECIFIED
FOR 6-MC SUBSYSTEMS

(a) Video Spectrum
(b) Characteristics of Video Signal
(c) Impedance
(d) Nonlinear Distortion

(e) Stability
(f) Noise
(g) Attenuation Distortion
(h) Phase and Group Delay Distortion

3.2.3.2.3.8 *6- or 12-mc Line Equipment on 0.375 Inch Coaxial for Television.* This section describes the overall television performance between video switching points. (See figure 3.2.3.2.3.7a.)

3.2.3.2.3.9 *Video Spectrum.* The spectrum for video transmission shall be 30 cps to 5 mc. (See figure 3.2.3.2.3.7.)

3.2.3.2.3.10 *Characteristics of Video Signal.* The polarity of the video signal is under study.
The dc component (not transmitted) shall not dissipate more than 0.5 watts in the input impedance.
The amplitude shall be 1 volt double amplitude peak (DAP) with a picture to sync ratio of 70:30 at the video switching point.

3.2.3.2.3.11 *Impedance.* The impedance shall be 75 ohms at input or output terminals of video points with a return loss of not less than 24 db.

3.2.3.2.3.12 *Nonlinear Distortion.* The relationship between input and output vision signal amplitudes is such that the mean value of the output signal is within ±10 percent of the input of the vision signal over the whole range of the input vision signal from black to white level.
Synchronizing pulses at the output shall not differ from the input pulses by more than 3 percent of the peak-to-peak amplitude of the composite video signal.

3.2.3.2.3.13 *Stability.* For short periods, for example 1 second, the stability shall be maintained to ±0.3 db. For medium periods, for example 1 hour, the stability shall be maintained to ±1 db.
For long periods, for example 1 month, the following conditions shall be met: If the circuit is not adjusted before every transmission, the stability shall be maintained to ±2 db. If the circuit is adjusted before each transmission the stability shall be maintained to 1 db.

3.2.3.2.3.14 *Noise.*

(a) Weighted Noise. Random (uniform) noise ratio, DAP picture/DAP noise, shall be greater than 30 db where the noise is weighted in accordance with curve E of Document 35 of the CCITT.

(b) Impulsive Noise. The impulsive (short duration slow repetition) noise ratio shall be greater than 25 db (DAP picture/DAP weighted noise).

(c) Pattern Noise. The pattern noise ratio shall be greater than 50 db (DAP picture/DAP weighted noise) up to 1 mc falling to not less than 30 db at the highest frequency.

3.2.3.2.3.15 *Distortion.*

(a) Attenuation Distortion. The attenuation distortion shall not exceed the following values.

±1 db up to 2 mc
±2 db up to 2 mc to 4 mc
±3 db up to 4 mc to 5 mc

(b) Phase Distortion. The phase deviation from 30 cps up to 4 mc shall not exceed 5° at 3.6 mc equivalent to (.004 ms time delay).

(c) Group Delay Distortion. From 2 mc to 4 mc the spread of the variation in group delay shall not exceed 4 microseconds, and from 4 mc to 5 mc 1 microsecond.
The change of group delay in 100 kc intervals shall be less than 0.1 microsecond.

3.2.3.2.3.16 *Line Equipment on 0.163 Inch Small Core Coaxial Subsystems.* Unlike the main line systems covered by sections 3.2.3.2.3 and 3.2.3.2.4, the "small core" coaxial subsystem is full transistorized and although conforming to long distance standards, shall be used primarily for medium haul application. The subsystem is suitable for inclusion in the hypothetical reference circuit described in 3.2.3.1.1.
The parameters specified for the small core coaxial subsystems are listed as follows:

(a) Capacity of Subsystem
(b) Frequency Allocation
(c) Pilot Frequencies
(d) Attenuation vs. Frequency Characteristic
(e) Total Noise
(f) Crosstalk
(g) Repeater Spacing

3.2.3.2.3.17 *Capacity of System.* The two core arrangement shall provide bandwidth for 300 high grade telephone circuits over medium haul distances. This means that up to about 270 nM of this facility may be included in the 6,000 nM hypothetical circuit without degrading the overall performance.
The single core arrangement shall provide 120 telephone circuits.

3.2.3.2.3.18 *Frequency Allocation.* The frequency spectrum for the small core subsystem shall be as shown in figure 3.2.3.2.3.19.

3.2.3.2.3.19 *Pilot Frequencies.* Pilot frequencies and number of supergroups for the small core subsystem shall be as listed in table 3.2.3.2.3.19 and shown in figure 3.2.3.2.3.19.

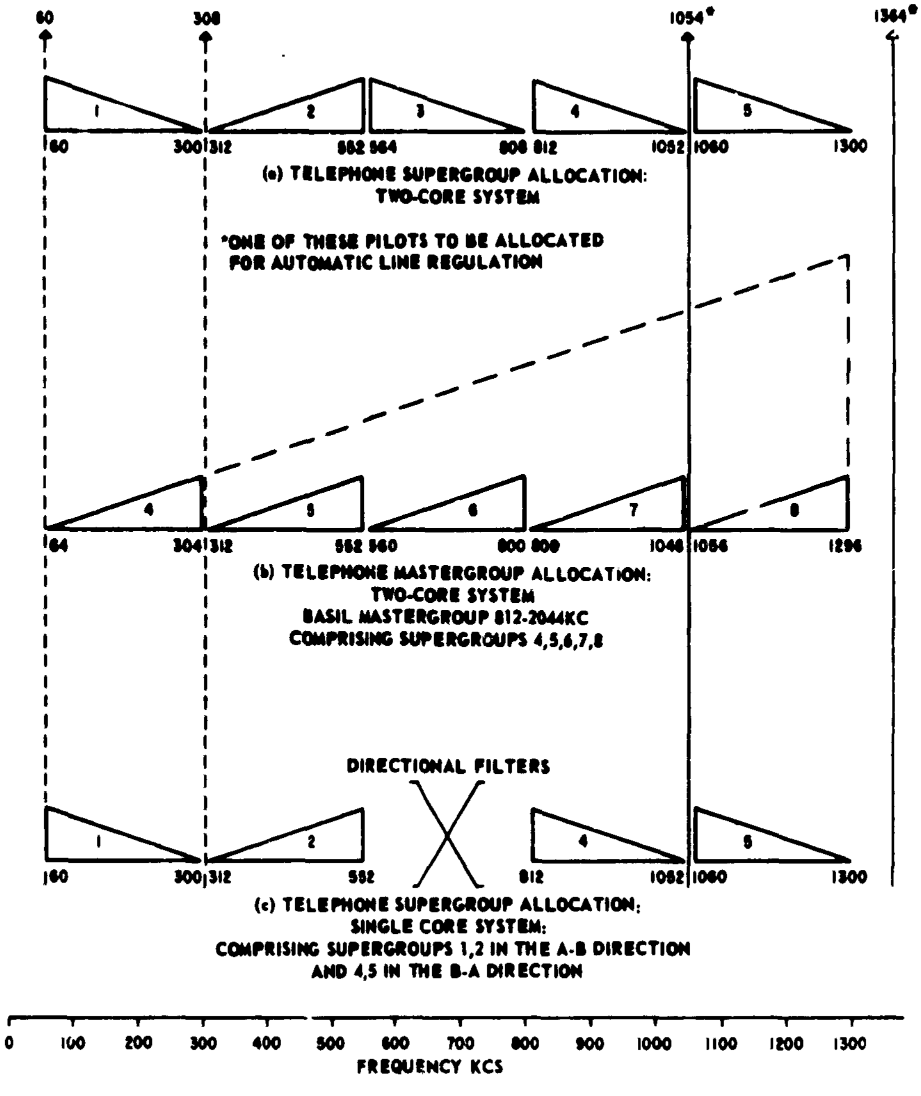
Table 3.2.3.2.3.19. Pilot Frequencies for Small Core Subsystems

	Two core	*Single core*
Number of supergroups	5	2
Pilot frequencies used for automatic line level regulation	1054 or 1364 kc in either case	
Frequency comparison pilot	60 kc	60 kc
Optional manual adjust pilot	308 kc	308 kc

3.2.3.2.3.20 *Attenuation vs. Frequency Characteristic.* At the time of lineup after assuring primary power supplies within the specified limits of ±5 percent, the spread of the attenuation frequency response between HFRDF and HFRDF over a distance of 180 nM shall not exceed 3 db. The spread on any supergroup shall be less than 1 db.

3.2.3.2.3.21 *Total Noise.* The total mean weighted noise in the band occupied by any standard channel (300 to 3,400 cps) shall not exceed 3 picowatts times the length of the cable route in nautical miles.

3.2.3.2.3.22 *Crosstalk.* The worst value of near-end or far-end crosstalk ratio on the 180 nM terminal shall not be less than 85 db at the lowest transmitted intelligence frequency, or 60 db at the highest transmitted intelligence frequency.



SMALL CORE COAXIAL BASEBAND FREQUENCY ALLOCATIONS

Showing Alternates A and B for Two-Tube Working and Method C for Single Tube operation

Figure 3.2.3.2.3.19.

3.2.3.2.3.23 *Repeater Spacing.* The repeater section planning length for buried cable is 1.97 nM (4,000 yards at 10° C.). (See figure 3.2.3.2.3.6.) For aerial or buried installation, the section planning length may be derived from the formula

$$1.97\ (1+0.0018(10-T)$$

where T is the mean annual temperature of the cable in °C.

The regulation system shall be capable of correcting for temperature variation of $\pm 30°$ C. for aerial installations and $+15°$ C. for buried installations. In either case, the dependent repeaters themselves shall be buried underground.

3.2.3.2.4 *Submarine Cable.* Standards for submarine cable systems are under investigation. Provisionally, noise for the system, exclusive of multiplex equipment, shall not exceed 1.5 picowatts per nautical mile.

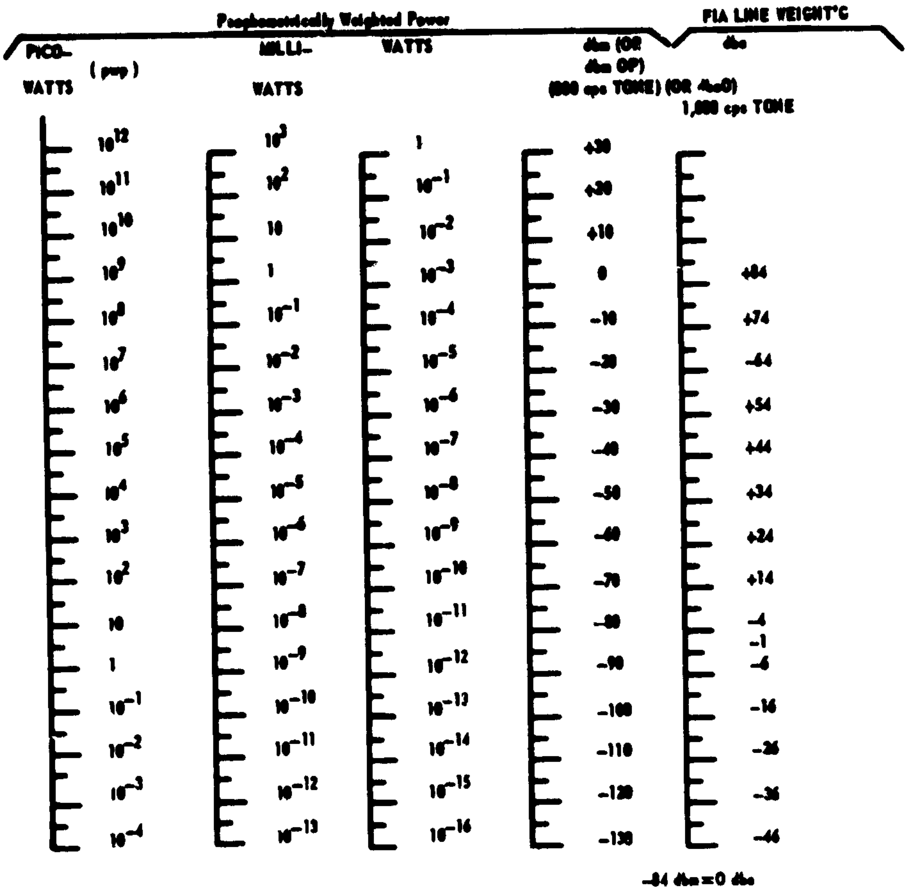
CHAPTER IV

TACTICAL COMMUNICATION SYSTEM

CHAPTER V

STANDARD MEASUREMENT TECHNIQUES

dba = (10 LOG_{10} PICOWATTS) −6 = dbm(p) +84



RELATIONS BETWEEN dba & PSOPHOMETRICALLY WEIGHTED NOISE POWER UNITS

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